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EDITORIAL NOTES.

IN the list of those recommended by the Council for election to the Royal Society is included the name of Mr. A. Hutchinson, President of the Mineralogical Society. Mr. Hutchinson is well known for his researches on the chemical, physical, and optical characters of minerals. He has designed many ingenious pieces of apparatus in connexion with his special studies on these lines, and has effected many improvements in the methods of teaching mineralogy and crystallography at Cambridge. Professor D. M. S. Watson, whose name also appears in the list, was recently appointed to the chair of Zoology at University College, London. He has done much work in Vertebrate Palæontology and has been a contributor to the GEOLOGICAL MAGAZINE.

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WE are glad to hear that the sale of collections of rocks and minerals in aid of the Cornish Miners' Relief Fund has proved very successful, and that over £50 has already been raised by this means, while orders are coming in steadily. One result of this large demand is that there may be some slight delay in the delivery of the collections, since the time at Mr. Davison's disposal for this work is somewhat limited, and such a large demand was scarcely anticipated; however, all orders will eventually be filled in strict rotation as received.

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SOME time ago we received from a correspondent and contributor a suggestion that is worthy of consideration. At present there are many geologists in this country who have already taken up or desire to take up some particular subject of research; in fact, so many that there is danger of overlap and duplication. Our correspondent therefore suggests that the GEOLOGICAL MAGAZINE should start a kind of bureau for the registration of subjects of research. There is no doubt that any clashing of interests of this sort is most undesirable, and may possibly give rise to unnecessary friction between workers in geology. If any general desire should be expressed for a record of this kind we should be most happy to afford space in the Magazine for brief statements of the work which our readers are engaged in or propose to take up. Then in case of any overlap the parties concerned could settle their differences between themselves. We should, however, in any case, decline emphatically to act in any way as arbitrators in such matters, and would disclaim all responsibility except that of making known the facts. We invite correspondence on this subject, for publication or otherwise, as desired by the writers.

ORIGINAL ARTICLES.

The Geology of Ascension and St. Helena Islands.

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THE writings of Charles Darwin, Renard, Mellis, Reinisch, and others have already made the salient features of lonely Ascension and St. Helena accessible, if not familiar, to geologists—St. Helena has won the surprised interest of biologists, who have long speculated on the origin of its unique species of plants and animals. From each island collections of rocks have been made. Following Renard's well-known contribution to the petrography of Ascension ("Challenger" Reports, Physics and Chemistry, vol. ii, 1889), Reinisch's paper in the Report of the Deutsche Südpolar Expedition (1901–3) gives a large number of petrographical descriptions, including a goodly number of chemical analyses. No adequate geological map of either island has, however, been published, nor, indeed, was this really possible before the British Admiralty had issued the greatly improved chart (No. 1691) of Ascension, in 1910, with corrections added to the year 1921, and the British War Office had issued its excellent contour-map of St. Helena, dated 1904. Each map is on a large scale. Even, though lacking contour lines, the Ascension chart was obviously to be of service to anyone attempting a reconnaisance survey of that island.

As a member of the Shaler Memorial Expedition, sent by Harvard University to carry out geological investigations in the South Atlantic and in South Africa during 1921–2, the writer has been privileged to complete a reconnaissance map of each island, and thus make more definite the available information. Since it will be long before maps and full reports can be published, a summary is herewith presented. This account will be best followed if read alongside of the topographic maps mentioned.

It is a pleasure to record the many courtesies extended by the Admiralty officials, who alone could give permission to land on "His Majesty's Island, Ascension", and those extended by the officials of the Colonial Office, both in London and St. Helena. Special acknowledgment must be made of the efficient, generous help of Major C. A. Tennyson, Naval Commandant of Ascension, and of his staff, as well as similar aid given by Governor R. F. Peel, of St. Helena, and his staff. Other valued privileges were extended by officers of the Eastern Telegraph Company, and of the comfortable steamships of the Union-Castle line.

Ascension.

The 38 square miles of Ascension are almost treeless. Except on a few young lava-fields and over some rugged ground in the eastern part of the island, travel is easy. The summer climate,

like that of St. Helena, is highly satisfactory to a field-worker. Hence it proved possible to make a fairly comprehensive study of Ascension, notwithstanding the shortness of the available time—twenty-seven days, chiefly in the month of November, 1921.

Ascension presents an ideal case of a complex volcanic island in its constructional stage. A half-dozen extensive lava-flows and a third or more of the sixty vents mapped look as if they had been formed not many centuries ago. So young are they, that one cannot but be surprised when one learns that no fumarole or hot spring is to be found. Apparently, too, no emanation of the kind is recorded in the early sixteenth century accounts of the island by the Portuguese. With marvellous directness most of the surface flows, cones, and craters tell their story. This is specially true of structures composed of basaltic or closely allied rocks. In all they cover about seven-eighths of Ascension.

Most of the cones shown on the chart are red, or red-brown, steep piles of scoriaceous agglomerates, tuffs, with steep-angled stubby flows of basaltic type interbedded. Examples are: East Crater, Holland's Crater, the Three Sisters, Perfect Crater, Traveller's Hill, Lady Hill, South-East Red Hill, Dark Slope Crater, Horseshoe Crater, Round Hill, Saddle Crater, Gannet Hill, Spoon Crater, South Red Crater, and Mountain Red Hill. Some of the crater rims, such as those of the first two mentioned, have been breached by outrunning basaltic streams, the breach being characteristically on the windward side. Mountain Red Hill, 1,786 feet in elevation, is the highest of these purely basaltic cones. The smallest are true driblet cones, illustrated in one series of three which are aligned on a fissure running north from the main crater of Sisters Peak, and in another line of a half dozen, strung out east of the breached basaltic crater of Booby Hill. Bear's Back, a craterless, basaltic plateau, with gently inclined surface, has no parallel in the island.

The many basaltic flows are rugged, often recalling the typical *aa* or blocky lava of Hawaii. Tumuli and hornitos of diagrammatic perfection are features of some of the flows. Ropy or *pahoehoe* lava and lava tunnels are rare. Pressure ridges and tensional gapings in the flows many times suggested the query whether those common features of low-angled flows are not analogies to the cordilleras and ocean-basin of the Atlantic type respectively, explained on the Taylor-Wegener theory of continental creep. As usual, the greater flows have issued from the flanks of the cones, rather than from the craters. Where they reach the sea they have been nipped by the waves, but the cliffs are generally low, witnessing to the recency of the eruptions. An exception to the rule is found in a 200-foot cliff at South-West Bay, probably an old sea-cliff, which has been largely covered by younger, thin, cascading flows. A new shore-line has there been formed, a few hundred yards to the west.

Darwin, Renard, and Reinisch have shown that alkaline trachytes are important in Ascension, and a leading purpose of the writer has

been to make clear the structural and age relations of the trachytes to the basaltic types. The trachytes cover the remaining one-eighth of the island, being most developed in the higher, south-eastern part. In apparently every instance the trachyte has risen at central vents, drilled or melted up through older, basaltic flows and pyroclastic beds. This relation is illustrated at the Devil's Riding School, where the old crater of a basaltic cone was filled with highly viscous trachytic magma, which flowed over the rim on the eastern side. Following the outflow, the surface of the trachytic crater-filling sank, giving a basin probably more than 100 feet deep at the centre. The area of the basin is nearly equal to that indicated within the crater-rim sketched in the chart. For a considerable time the basin contained a freshwater pond, in which were deposited the fossiliferous beds described by Darwin and Ehrenberg. A similar basining has affected a trachytic crater-filling, one quarter of a mile north-west of the Thistle Hill.

In most cases, however, the viscous trachyte assumed the form of great domes projecting high above the old crater rims. Ideal examples are found in Ragged Hill, Little White Hill, and Weather Post. Cross Hill is of greater complexity. Its core is a broad dome of trachyte reaching a height of 600 feet above sea-level. The dome rose about 400 feet above the rim of an older basaltic crater and later became vencered with basaltic agglomerate, tuff, and driblet flows to a depth of 200 feet or more. Green Mountain (elevation, 2,817 feet), the highest cone in Ascension, is another composite. Its visible base is a large basaltic cone truncated by a major explosion. Into the resulting caldera a trachyte dome rose, to a height of nearly 2,400 feet above sea, and sent short, thick flows toward the Riding School and the Bear's Back. The eastern part of the dome and the trachyte flows alongside were blown away by a second explosion, forming another caldera, nearly a mile long and 1,000 yards wide. This caldera in its turn was completely filled with basaltic tuff, which from a central vent was built up to a height somewhat greater than 2,817 feet, the present elevation of "The Peak" of Green Mountain.

The most voluminous effusion of trachyte was that of the Weather Post dome, rather more than 2,000 feet high and the source of a northbound flow; this flow is more than a mile wide, nearly two miles long, and several hundred feet in maximum thickness. Three major explosions followed the solidification of the Weather Post dome. The resulting calderas are the Devil's Cauldron, Cricket Valley, and the even grander, more irregular basin above Spire Beach. Most impressive is the heavy burden of coarse débris spread over basalts and trachyte alike, and as yet almost unaffected by erosion or by a concealing cover of vegetation.

Another trachyte dome composes nearly all of South-East Head. A smaller dome, of the same type of pale-grey trachyte, capped with black basalt, which seems to have been pushed up by the

rising dome, is represented in Wig Hill. Boatswain Bird Island, a spectacular monolith of trachyte, is probably an independent dome. Crags of still another crop up through a veneer of younger, basaltic cinders, a short mile north-north-west of Sisters Peak. An extensive mass of trachyte, exposed in the cliffs of Coco-nut Bay, may represent a tenth dome, which has been largely cut away by the heavy surf of this windward side of the island. Finally, White Hill may be the remnant of a dome erupted independently of the adjacent Weather Post body.

As crater-fillings or domes, the trachytic masses are in wonderfully clear relations to the basalts. All are younger than the bulk of the basalts. On the other hand, in each of several instances the trachytic effusion is but an interruption in a series of basaltic eruptions. That basalts have followed, as well as preceded, the trachytes is shown at Cross Hill, Green Mountain, and, again, with extraordinary vividness at South-East Head. Quite across the Head an east-west fissure opened, not many centuries ago, and from it streams of black basalt flowed out on both sides, over the bare pale-grey dome of trachyte. The intensity of colour contrast between the two kinds of rock, the gaping crack a mile or more in length, and a row of small craters blown open along the fissure show in perfect fashion elementary principles of volcanism and, as well, the syngenesis of basalt and trachyte.

Considering Ascension as a whole, one may fairly question that any other equal area displays more eloquent and at the same time more varied examples of volcanic activity.

Like the similar trachytes of crater-fillings and domes in Samoa, those of Ascension are singularly prone to alteration, rapidly becoming friable to a depth of several feet. These bodies, monolithic as they are, yield to weather and wave, and are ravined and cliffed at a rate much faster than is the case with the basaltic flows. Large-scale, carious weathering of the trachyte produces characteristic hoodoos, bizarre turrets, and other fantastic shapes.

The writer was able to add some details to Darwin's description of the granitic fragments brought to the surface by the volcanic eruptions at Ascension (see Renard for references and discussion). Many fragments of hornblende-granite and probably other plutonic rocks were found in both the basaltic and trachytic agglomerates of Green Mountain, the source of Darwin's collection. Two new localities were found. The basaltic *flows* issuing from Dark Slope Crater are charged with numerous angular to subangular inclusions of granite, the largest seen measuring 2 feet in length. The other locality is three miles to the northward, where the massive trachyte of the monolithic *dome* north-north-west of Sisters Peak was found to enclose at least one angular fragment of granitic rock. Since the parent body, whence the inclusion was torn, is likely to have been at least 9,000 feet below sea-level, this discovery seems to show that trachytic magma is generated at considerable depth. The existence

of these granitic rocks in Ascension has manifest bearing on the origin of the Atlantic basin.

Another observation, perhaps of importance to the genetic theory of trachyte is, that, while there are numerous thin beds of trachytic pumice, tuff, and breccia (enclosing small masses of obsidian) in the island, the great domes and flows of trachyte, at both floor and original surface, are practically free from gas-vesicles of the ordinary bubble form. The same is true of the visible parts of the trachytic bodies in Hawaii and Samoa. The contrast with the dominant, highly vesicular basalts, thus repeatedly shown, is a problem deserving attention. Do the magmatic gases *escape* upwards, while femic crystals or their non-consolute equivalents *sink* during the prolonged differentiation of basaltic magma, leaving a gas-poor, alkali-rich, siliceous melt—a derived, trachytic magma?

Pending laboratory study, it is impossible to state the range of composition represented in what have been above described as "basaltic" rocks. Flows of true olivine basalt are not uncommon, and a beach-sand, very rich in olivine, is found at Crystal Bay. Olivine-poor and olivine-free basalts of various textures are more abundant. Both andesitic and trachydoleritic types may be demonstrable.

Five narrow dykes represent the only intrusive bodies discovered. In view of the island's extreme youth and the absence of important faulting, the rarity of visible intrusives is not surprising.

St. Helena.

Seven hundred miles south-eastward of Ascension is St. Helena, covering nearly 50 square miles, and thus a little the larger. The last month of 1921 was spent on this Gibraltar of the South Atlantic. It is essentially an older Ascension, submaturely dissected by streams, ancient and modern. On the steep valley walls, reaching 1,000 to 2,000 feet in depth, as on the magnificent sea-cliffs of similar maximum heights, one can see well down, and with unusual clearness, into the sub-surface mechanism of volcanic vents. The one exemplifying constructional forms so brilliantly, the other exemplifying the correlated structures underground, the two islands are, therefore, complementary to each other. From them alone most of the essentials of a textbook of volcanic geology could be well illustrated. In St. Helena also the advantage given the geologist by the absence of a forest cover was specially appreciated by one who had recently tried to make out the history and volcanic mechanism of the Samoan Island of Tutuila, most of which is covered with a smother of jungle. Accessible by regular steamers, covered with good paths and roads, its rocks exposed with a completeness seldom matched, and, above all, intrinsically important, St. Helena should be visited, if possible, by every specialist in igneous geology. The publication of the reconnaissance map should at least help to advertise the worth of this choice place of the earth to the student of volcanoes and of erosion.

But another fact stimulated the wish to explore St. Helena. Reinisch, in the paper above noted, states that a graywacke, consisting of many pieces of quartzitic schist, quartzite, sandstone, granite, gneiss, and other "continental rock types", had been found in the "Laing-Berge" of St. Helena. This announcement is so weighty in the theory of Gondwanaland that further data of the kind seemed desirable. So far as that object is concerned, the writer has had negative results. In spite of constant search, neither the graywacke nor any other quartz-bearing or "continental" rock was found. "Laing-Berge" is a locality unknown to St. Helenians. Is it possible that Reinisch's specimen was brought from near Laingsburg, South Africa, by the same Boer prisoner, interned at St. Helena, who collected the specimens of St. Helena lavas described by Reinisch?

St. Helena is largely composed of basaltic rocks, olivine-bearing and olivine-free. They will probably be found to duplicate some of the Ascension types. These rocks form superposed, generally thin, flows, which with thin interbeds of tuff and rarer agglomerates constitute the greater part of the island; trappean, vesicular, and porphyritic dykes cutting the flows are exposed in hundreds; several large areas of remarkable complexes, made up of thick masses of tuff which are cut by multitudes of simple dikes, many multiple dikes, and many dike networks; a number of volcanic necks, and monolithic crater-fillings; and at least one sill.

The tuffs and associated agglomerates of the complexes are the oldest rocks. In some respects the most notable complex is that covering about 1·5 square miles at the north-east corner of the island, stretching from the middle of the shore of Flagstaff Bay, between the line of heights from Flagstaff Hill, through Woody Point to the Turk's Cap on the one side, and The Barn on the other. This may be called the Knotty Ridge Complex, from the name of a prominent feature in the broad belt. Darwin (in his *Volcanic Islands*) and Mellis (in *St. Helena*, London, 1875) give good descriptions of it, but even the previous reading of their books did not prevent astonishment at the actual profusion of dikes. These trend in all azimuths. The more conspicuous dikes are grouped in two systems. The one comprises dikes, generally vertical or nearly so, whose outcrops run in a north-east—south-west sense, the strike varying from north 20°–30° east (common readings) to north 80° east. The average trend of this system, specially well seen from the ridges south-west of The Barn, agrees fairly well with the more regular north 40°–45° east trend of the main dike system in a similar basal complex of the Sandy Bay district. The second system of the Knotty Ridge dikes varies in strike from north 10°–15° west (common readings) to about north 10° east. Many dip 70° or even at 60° to the westward, indicating unusual conditions of tension in the older rocks. The dikes range in width from an inch or less to a score or more of feet in width; the average is perhaps four feet.

This area is dangerous for climbers. Its slopes tend to become veneered with a coat of creeping, tuff-like mud, which greatly obscures details. Hence a complete study of the dikes is a very slow, if not impossible task. At several points, however, it was seen that the intrusions form most unusual examples of multiple dikes. As many as twenty contact directly with each other in succession, without any intervening tuff or other material. So crowded are they in the middle of the ridge joining Flagstaff Hill and The Barn that some 200 of the sheets of rock seem to constitute one gigantic multiple dike. In the writer's experience this part of the complex is quite peerless for the number of distinct, basaltic intrusions outcropping in so small a space. The nearest parallels to such persistence of igneous injection are perhaps the belts of "inclined sheets" in the Scottish islands of Mull and Skye, though the causes of tension and injection may be essentially different.

Other dikes of the Knotty Ridge complex, having trends unlike those of the two principal systems, and combined with the latter, constitute dike networks of unmappable complication.

From the lips of many of the Knotty Ridge fissures, and presumably from others not yet exposed by erosion, lava-flows were poured out. The result was a high, exogenous, basaltic dome, which centred nearly under Deadwood Plain. From that general centre the thin flows ran on slopes that decreased from 25° to 10°, as far as Jamestown on the north-west and Sane Valley on the south-west. Flagstaff Hill and The Barn are erosion-remnants of this thick capping of many flows, which formerly covered the whole of the visible Knotty Ridge complex as well as its continuation in Flagstaff Bay.

No volcanic neck is exposed, and, as throughout the island in general, the growth of the north-eastern end of St. Helena was due to fissue-eruption rather than to eruption from local, persistent vents of the central type. Scores of dikes cut the capping flows of Flagstaff Hill and The Barn. The flows are massive and strong; the complex is remarkably weak and friable. Hence have been conditioned some of the finest canyon-like scarps and sea-cliffs in the island.

A very similar complex covers nearly 3 square miles in the lower part of the basin comprising the Sandy Bay district. In the writer's opinion, this huge cirque is neither a crater nor a caldera, but owes its imitative shape to erosion, working on a special structure. Erosion was bound to begin the widening-out of just such an amphitheatre as soon as the weak rocks of the underlying complex in their actual distribution were uncovered.

Hundreds of dikes of the Sandy Bay Complex, including many dikes, generally run parallel, in a north-east — south-west direction, on which some of them keep for nearly 3 miles. Dikes of similar trend were found far to the north-eastward of the Sandy Bay district. As near Deadwood, the dike fissures here were vents through which many lava-floods were emitted. The lavas ran in all

directions, but the total result was an elongation of the island in the sense of the dominant system of fissures. Nevertheless, the flows visible in nearly two-thirds of the island emanated from the fissures concentrated in the Sandy Bay district. This region, before erosion had far advanced, was a low-angled, exogenous, basaltic dome, the flows of which dipped seaward on all radii, at an average angle of eight or ten degrees. At the headwaters of Jamestown and Rupert's valleys the Sandy Bay flows are seen to cover and wrap around the steeper flows from the older Knotty Ridge–Deadwood centre.

A third concentration of fissures feeding lava-flows was located under the sea, just off the shore of Manatee Bay. Flows and dikes originating in that area are to be seen in the majestic Man-and-Horse cliffs.

Only one sill was demonstrated in the island. This is exposed in the valley-wall near Wild Cattle Pound and close to High Hill. It is a columnar lens nearly 40 feet thick in the middle and about 500 yards long on the outcrop. It transgresses a few of the invaded flows of basalt.

Some of the St. Helena fissures have been locally enlarged into "necks" by explosion or by the melting action of blowpiping gases. Monolithic bodies of rock, resisting erosion better than the lavas and tuffs surrounding them, represent these exceptional, truly "central" vents. In some instances remnants of the corresponding steep cones of tuff and centrifugal flows were mapped. This is true even at High Knoll and High Hill, where the necks are, in ground-plan, elongated in the directions of the locally dominant dikes, so that the hypothesis of local widening of the fissures is rendered very probable. The largest neck is at Sliding Stones Hill in the Sandy Bay district. There the widening seems to have affected at their intersection two master dikes running nearly at right angles to each other. The High Hill neck is similarly shaped and similarly interpreted. In each case, enlargement of the fissures through the melting of the country-rock is specially suggested by the ground-plan of the neck. More nearly cylindrical necks were mapped: at the hill crowned by the Baptist Chapel, Sandy Bay; at the superb, well-known pyramid called "Lot"; at Castle Rock (Man-of-War Roost); Hooper's Rock; Sheep Knoll; and at two bold crags in Powell valley, respectively east and south-east of White Hill.

Some of these "necks" may be the monolithic fillings of craters, such as would be formed if the Kilauea lava-lake of Hawaii were to solidify during a high stand of the lake-level. Such a body would be a "head" rather than a "neck", the "neck" being below and invisible.

Scenically imposing as the "necks" or crater-fillings are, the output of the flows from these centres was probably very small, when compared with the eruptions from the normal, narrow fissures. Though the "necks" are most numerous in the Sandy Bay amphitheatre, none of them appears to have long functioned as a centre

of extrusion. The building of the great, composite, exogenous Sandy Bay dome was rather due essentially to eruptions from many fissures, which were opened in special abundance over an area measuring at least 3 miles by 2 miles. In that sense Sandy Bay was the chief "centre" of eruption in St. Helena.

In relation to that area of concentrated fissuring, the vents at High Hill and High Knoll have the positions of "subsidiary" or "parasitic" cones, but both of these local vents are likely to have been occasioned by fissuring which was independent of that registered in the remarkable dike-system of the Sandy Bay district. Another outlying vent formed an unusually high cone of tuff, with some basaltic flows, on the ridge north of Swanley Valley, around "The Saddle". Several local tuff-cones, which had been deeply buried under lava-floods, are exposed in sea-cliffs and canyon walls.

Two local vents, at Little Stone Top and Great Stone Top, are of special importance, since their effluent lavas are alkaline rocks, very like the Ascension trachytes. For preliminary descriptions these rocks may be called trachyte, though laboratory study may show the need of a different designation. At Little Stone Top the trachytic magma seems to have risen in the form of a dome, greatly broadened at the orifice and finally overflowing. One flow, 300 feet thick, is now represented in remnant by Ben Coolen ridge; another outflow constitutes Boxwood Ridge; a third crept down toward the base of Great Stone Top.

The vent by which the trachyte of Great Stone Top came up is exposed on the shore near Elephant Rock. It is a dike-like pipe, apparently about 300 feet long and between 30 and 60 feet in width. One of its chilled contacts with the older flows of basalts is admirably exposed. The contact with the gently dipping basalts is here nearly vertical. Thence the trachytic magma rose along a dike fissure obliquely, so that the upper part of the injection dips 60 degrees to the eastward. Near the 800-foot contour the magma reached the surface and spread out as a dome. The cap of this mushroom-shaped eruptive is now 900 feet thick, after losing some of the original thickness by prolonged erosion.

In the cliffs due south of Little Stone Top, the older basaltic flows, dipping about 10 degrees to the eastward, have been bent up anticlinally by a thick wedge (or chonolith ?) of trachyte, which is purely intrusive. The apex of the wedge is visible in the sea-cliff at the 500-foot contour. The force of the injection sufficed to steepen the dip of the invaded flows on the eastern side of the wedge to 20 or 25 degrees, and on the west to change the dip to 45 degrees to the westward. Alongside is a 60-foot, inclined dike of trachyte, conspicuous in the sea-cliff. A long, 15-foot dike of trachyte cuts the basalts a little to the south-east of Ben Coolen ridge, and ranging with it, towards Little Stone Top. This completes the list of known occurrences of highly alkaline bodies in St. Helena, but possibly some of the necks of the Sandy Bay district will prove to be allied types of rock.

Thus, St. Helena, like Ascension, once more shows the closest genetic connexion of alkali-rich rocks with common basalt. Here, too, the solution of the problem of origin may be affected by the fact that nowhere was the effusive trachyte of St. Helena found to be vesicular in the ordinary sense of the word when referring to lavas.

The writer was able to confirm Melliss's discovery of the casts of sizable tree-trunks in the lava flows exposed on the slopes of the arid Jamestown Valley and 800–1,000 feet below the surface of the uppermost flow in the valley walls. The casts occur in two different flows, stratigraphically about 100 feet apart. These facts show that the upbuilding of St. Helena may have been as leisurely as the growth of Hawaii to similar height, and that St. Helena also possessed a climate which was considerably moister than that now ruling. It proved impossible to procure evidence as to the specific nature of the trees represented by the casts.

No other fossils tending to fix the age of the island were discovered. As at Ascension, no palæontological discoveries of moment were made. In Ascension, except lithified, calcareous beach-sand, a few feet above high-tide level, and the crater-lake deposit at the Riding School, and, in St. Helena, some poorly cemented, calcareous dune-sands at various elevations up to about 700 feet above sea, no sedimentary rocks were found. From the youth of its topography, little, if any, of the visible Ascension is likely to antedate the Recent period. St. Helena has suffered denudation and sea-cliffing to such degrees that a late Tertiary origin seems preferable to one even in the early Pleistocene.

Except for some possible indications near Georgetown, at English Bay, and at South-west Bay, Ascension shows no evidence of emergence. The obscure features at the three localities named could mean emergence no greater than 20 feet. A eustatic, world-wide fall of ocean level seems to be deducible from a statistical study of "elevated" strand-marks around the different oceans. St. Helena confirms that deduction in a striking way. On its leeward side were found numerous sea-caves and rock-benches at heights above high tide of exactly the same order as among the Samoan Islands, where the hypothesis of this particular eustatic shift first took definite shape.[1] This correspondence between islands on opposite sides of the world is manifestly difficult to understand on any other hypothesis. As in Samoa, no evidence of emergence to an amount greater than 20 feet was found at either of the Atlantic islands.

If the eustatic shift of about 20 feet is to be correlated with the "elevated" Neolithic beach of north-western Europe, which appears to be nearly 5,000 years old, then we may have a possible means of assigning a minimum age to the oldest lavas of Ascension. More certain would be the possibility of gauging the speed of the erosion

[1] Geol. Mag., Vol. LVII, 1920, p. 247.

of hard lavas of St. Helena by the untiring waves. On the windward side of that island, the 20-foot strand marks have apparently been already destroyed. The more moderate, though absolutely powerful surf on the leeward side has damaged the 20-foot benches, but has left many remnants. From these, when compared with the initial shapes and volumes of the benches, it is clear that the sea-erosion is exceedingly slow. The stupendous cliffs of St. Helena seem to represent a duration of wave-attack which may be reasonably guessed as more than 2,000,000 years.

Barring a fault, visible in the north-eastern sea-cliffs of St. Helena—a displacement of about 30 feet—a few insignificant slips seen in tuff-beds, and the local deformations incidental to igneous injection, the island seems free from the effects of diastrophic processes. The field evidence points to the conclusion that St. Helena has neither sunk nor risen for a very long period of time, if, indeed, it has moved at all since the distant epoch of its last eruption. Ascension, too, shows no indication of having either risen or sunk since its beginning as an island.

In 1923 the writer hopes to publish the geological maps and the details of his studies on these instructive islands. The results are, of course, but supplementary to Darwin's classic descriptions in his *Voyage of the Beagle* and *Geological Observations on Volcanic Islands*. Anyone honoured with the opportunity to follow the very paths he trod in out-of-the-way places cannot merely admire his famous accuracy and thoroughness of observation. Even more impressive is the evidence of Darwin's intellectual initiative in the field of geology. He created much of the technique of the science; most literally he was one of its founders. In the main Darwin's descriptions of these islands are amazingly full and true to the objective facts, because he had the genius to discover the vital problems and to invent the technique for handling them, as, alone and single-handed, he attempted the mysteries of the volcanic islands. A few changes in his theoretical conclusions are necessary, chiefly because he lacked the methods of study which three generations of geologists have since developed. The principal changes refer to the relations between the basalts and trachytes of Ascension (where he failed to discern the superposition of the trachytic bodies on the older series of basalts) and to the nature, location, and physiographic development of the volcanic vents and magmatic types on St. Helena.

On the Overlap of the Upper Gault in England and on the "Red Chalk" of the Eastern Counties.

By F. L. Kitchin, M.A., Ph.D., and J. Pringle, F.G.S.

I. Introduction.

During the years 1918–19 we investigated the relations of the beds exposed in a remarkable section at Shenley Hill, north of Leighton Buzzard. Our conclusion that lenticles of limestone of

basal *varians*-age are there overlain by a mass of Upper Gault showing an inverted order of zones provided an interesting glacial problem. This seemed to us of less importance, however, than the discovery that these transported masses had been deposited upon a floor formed by a basement-bed of transgressive Upper Gault, which there rests immediately upon the local top of the Lower Greensand.[1] The chief interest attaching to this example of glacial disturbance lay in the resulting disposition of particular beds in anomalous zonal relationships. Other striking instances of the glacial transportation of large masses of rock were known to occur in the tract of country to the north-east of this locality. The difference was chiefly one of degree, not of kind. We realized that the detection here of an overlap of the Upper Gault might prove to be a matter of greater moment, possessing, perhaps, a far-reaching stratigraphical significance. A study of the literature dealing with this formation, coupled with the examination of the Gault at a few localities in other counties where an overlap takes place, convinced us that a fuller investigation of the subject would prove fruitful in results.

It was evident that the occurrence of an Upper Gault transgression accompanied by erosion, in localities where it was previously unsuspected to occur, might explain much that was obscure concerning the relationship of the Gault to the underlying rocks. We therefore planned out a programme of work which included some examination of the strata with which the Gault at various localities was known or suspected by us to have non-sequential relations. We also proposed to make a general study of the strata between the Aptian beds (below the *mammillatus*-bed) and the base of the *varians*-Chalk in different parts of the country, in order to ascertain with some degree of exactitude the chief evidences for movements of depression. To carry out the study on these comprehensive lines would have necessitated journeys to a large number of sections exposed in many counties; and since the whole investigation was unconnected with our current official work for the Geological Survey, we sought financial aid from the Royal Society. Our application to that Society for a grant for the furtherance of this projected research was unsuccessful. It therefore became necessary to curtail the scheme of work. Nevertheless, the results of visits we have made during the past twelve months to localities ranging from Dorset to Yorkshire seem of such interest that we now offer this short preliminary account of them in the belief that it may be of use to many geologists in this country. We hope to continue the study as opportunity occurs, and to furnish a more comprehensive account, with some description of local details, at a later date.

[1] F. L. Kitchin & J. Pringle, "On an Inverted Mass of Upper Cretaceous Strata near Leighton Buzzard, Bedfordshire; and on an Overlap of the Upper Gault in that Neighbourhood": GEOL. MAG., Vol. LVII, 1920, pp. 1–15, 52–62, 100–13.

It must be understood, in the first place, that to obtain sound results in an investigation of this character the fullest reliance must be placed on the value of palæontological evidence. Indeed, it must be insisted that in the study of the Cretaceous, as of other stratified rocks, fossils, when obtainable, provide the most important part of the whole evidence upon which sound stratigraphical conclusions can be based. In any attempt to determine the zonal relationships when studying deposits of clay such as the Gault, subject to lateral change to other types of sedimentation, we must be prepared to pin our faith entirely to the fossils. There remains, of course, the recognition of the species appropriate for such an important use and the power to apply this evidence legitimately, in the scientific sense. These are obviously matters depending entirely on the uniformity of previous experience and the competence of the individual investigator. We would not lay emphasis on preliminaries so trite were it not that in this country we still witness the publication of fallacious stratigraphical correlations that have resulted from failure to utilize the means at hand for arriving at a true interpretation.

The Gault Clay is usually poorly exposed, so that the investigation of its characters and relations, except at isolated localities, often distantly separated, is frequently a matter of much difficulty. In some districts, as in the Isle of Wight, there is a further obstacle in the masking and confusion caused by the slipping of the clay on an extensive scale. It follows, then, since exhaustive fossil-collecting can seldom be carried out, that it is necessary to use to the best stratigraphical advantage such fragmentary evidence as may be provided by the few fossils obtainable in obscure surface-exposures or in wells and borings. The chief requirement in the present connexion is to be able to determine with certainty whether the lowest member of the Gault seen at any given locality represents the true basal part of the Gault or the lower part of the Upper Gault. Only by ability to do this is it possible to avoid being misled by delusive stratigraphical appearances.

The true basal part of the Gault Clay, the so-called *interruptus*-zone, is highly fossiliferous, and always contains numerous well-ribbed hoplitid ammonites showing pronounced peripheral sulcation. These are frequently preserved in smooth phosphatic nodules with pale surfaces. The keeled ammonites are absent. We have found that the *interruptus*-Gault, wherever it has been seen in this country, rests always upon the *mammillatus*-bed. An unconformable junction with older strata may occur locally below that bed, as in North Dorset, but never at the base of the *interruptus*-zone. So invariable is this unity of the *interruptus*-Gault and its substratum that the direct superposition of Gault Clay or its equivalent upon any rock older than the *mammillatus*-bed suffices to negative the presence of the *interruptus*-zone.[1]

[1] Cf. C. Barrois, *Recherches sur le Terrain Crétacé Supérieur de l'Angleterre et de l'Irlande*, 1876, p. 7.

The lower part of the Upper Gault, the *rostratus*-zone (or "*inflatus*-zone") of stratigraphical classifications, yields numerous fossils that are not found in the Lower Gault. Species of ammonites that have been referred to alike under the name *A. varicosus* here make their appearance, and these, as well as a number of peripherally keeled shells, are readily distinguishable from any of the forms occurring at lower horizons. Species of well-ribbed hoplitid ammonites also occur. These bear considerable resemblance to the hoplitids of the *interruptus*-Gault, and have proved a stumbling-block for the unwary. When ill-preserved and crushed, they may be difficult to distinguish from the comparable forms of earlier date; when well-preserved, the character of their peripheral area, as pointed out to us by Dr. L. F. Spath, provides a good distinguishing feature. Some descendants of these species show in their individual development a rapid loss of the costate ornaments, so that the later growth-stages are devoid of ribs and only retain remnants of the sculpture at the umbilical and peripheral margins. Such forms occur in Price's Bed XI at Folkestone and in the sandstones below the Chert Beds of the Upper Greensand in the Isle of Wight, as well as in corresponding strata near Devizes. Specimens of them exhibited in museum-collections have been variously and erroneously labelled "*Ammonites auritus*", "*A. splendens*", "*A. catillus*", and "*A. auritus*, var. *catillus*". Certain well-sculptured hoplitids found rarely in the "Red Chalk" of Norfolk and Lincolnshire have been ascribed to "*Ammonites interruptus*". These are in reality species of the Upper Gault and cannot be used in support of the contention that the so-called Red Chalk represents the Lower Gault as well as the Upper Gault.

Other fossils which are of great stratigraphical value are *Inoceramus anglicus* Woods and *I. sulcatus* Parkinson. The first of these makes its earliest appearance at the base of the Upper Gault and is abundant at some localities, as at Speeton. *Inoceramus sulcatus*, recognizable even in a fragmentary state, is first met with in Price's thin Bed VIII at Folkestone. It occurs also in Bed IX, becoming large and abundant at the top of that bed, where it suddenly dies out. Its vertical range is similarly limited in other parts of the country. The reliance that can be placed on the evidence of the above-named *Inocerami* when applied to stratigraphical purposes rests upon abundant experience of their restricted range, and is strengthened by evolutionary considerations.

Although overlapping Gault has been described and mapped over extensive areas in this country, no attempt has apparently been made to ascertain whether this evidence of depression of the sea-floor points to one general movement or to several subsidences, leaving separate local effects. It seems to have been accepted that the Lower Gault is present at the unconformable junction in North Dorset, Wiltshire, Oxfordshire, Buckinghamshire, and Bedfordshire, where the mapping has established the general occurrence of a

Gault transgression. While Professor C. Barrois ascribed most of the transgressive Selbornian strata of South Dorset and Devon to the Upper Gault (his zone of *A. inflatus*), the late A. J. Jukes-Browne thought it probable that the Lower Gault is represented there in the lower beds.[1] In the case of the "Red Chalk" (or Red Rock) of Norfolk and Lincolnshire, conflicting opinions as to its age have given rise to such confusion and doubt that the close bearing of this deposit on the subject now under discussion appears to have been generally overlooked. Professor Barrois, we must mention, considered the Red Chalk of those counties to represent the Upper Gault; and so far as its lower three-quarters are concerned, we are satisfied that his correlation was the correct one. We shall state reasons for regarding the uppermost portion of the Red Rock at Hunstanton as part of the overlying Chalk.

The result of our investigation, so far as it has proceeded, has been to unify the facts and to convince us that one general movement was responsible for a transgression round the border-regions of the main basin of Gault Clay deposition in England. A consideration of all the palæontological evidence leads us to place the date of this movement at about the close of Lower Gault time. We think it probable that the character of Price's nodular "Junction Bed" at Folkestone (Bed VIII), which contains nodules and fossils in *remanié* condition, may be connected with the disturbance that gave rise to the transgressive extensions of the Gault in the marginal regions of the English area of deposition. The magnitude of this and subsequent movements and the widespread nature of their effects are shown by the occurrence of transgressions of the Upper Gault (Upper Albian) and lowest Cenomanian deposits in France and Belgium, in Africa, and in other distant regions.

II. Characters of the Gault in certain Localities.

Kent and Surrey.—In these counties, where the Lower Gault is present in normal development, always resting on the *mammillatus*-bed, there has not been observed any indication of the movement which produced the Upper Gault overlap, except perhaps at Folkestone, as mentioned above. In West Kent and in Surrey the Gault Clay is thickly developed and the detection of any effects of the movement at a particular level in the series is scarcely to be expected there. At the same time, there are indications of subsequent results in the introduction of an arenaceous facies in the *rostratus*-zone at the western limit of Kent and in Surrey. This change was doubtless connected with the process of shallowing which so affected the character of the sediments deposited subsequently to the date of the overlap in more westerly counties.

The Isle of Wight.—Inland exposures of the Gault are rare and unsatisfactory. In the hollow between Redcliff and Culver Cliff,

[1] *The Cretaceous Rocks of Britain*, vol. i, "The Gault and Upper Greensand of England": *Mem. Geol. Surv.*, 1900, p. 145.

near Sandown, the cliff-exposure of the Gault is for the most part rendered unfavourable for fossil-collecting by slipping of the clay and by a thick mantle of turf. A few feet of the lowest beds, immediately overlying the so-called "Carstone" of the Lower Greensand, were found to be exposed on the occasion of our visit last year; but the clay was much weathered and numerous crushed casts of ammonites were the only fossils obtainable. These are ribbed hoplitids, all in a state unfavourable for identification. Their abundance suggests strongly that the *interruptus*-zone is here present, and this is the accepted view of others who have studied this section.[1] It must be noted, however, that the mode of preservation of these fossils differs from that so generally found to hold good in the *interruptus*-Gault of most other localities in this country.

Between Luccomb and Bonchurch the Gault is obscured by the extensive débris of the great landslip, but phosphatic nodules containing ammonites referred to the *interruptus*-Gault have not infrequently been found on the beach below. At Blackgang we have failed to obtain access to any exposure of the Gault undoubtedly in place; but we have seen hoplitid ammonites of the *interruptus*-zone found at this locality.

At Compton Bay, near Freshwater, the characters of the lowest part of the Gault are well contrasted with those of the lower beds at Redcliff. The rock is of a more silty nature, and ammonites are extremely rare. The few lamellibranchs found by us included *Lima* (*Mantellum*) *gaultina* Woods, a species always common in the lowest part of the transgressive Upper Gault of the Dorset coast. *Inoceramus sulcatus* Parkinson has also been found in the lowest beds of the Gault here, as recorded by M. W. Norman. If the identification of this easily recognized species was correctly made, which there is no reason to doubt, the record of "*Ammonites dentatus*" from this locality must have referred to one of the Upper Gault hoplitids, so easily confounded with the earlier forms. In the light of our examination of the Gault along the coast of Dorset, we can only conclude that at Compton Bay the Upper Gault has overlapped on to the Lower Greensand. There is, indeed, doubt whether the so-called "Carstone" of this locality represents the true top of the Lower Greensand.

Dorset and Devon.—In South Dorset the Gault can be studied at Worbarrow Bay and at intervals westward as far as Holworth House, near White Nothe. From the published accounts of the section at Worbarrow Bay there is nothing to indicate the presence of any Lower Gault there. At that locality there is a marked line of erosion at the base and the Gault is in the condition of sandy and silty clays, as is also the case at Mupe Bay, where much of the section is obscured by talus.

[1] H. J. Osborne White, "A Short Account of the Geology of the Isle of Wight": *Mem. Geol. Surv.*, 1921, p. 51.

At Lulworth Cove, where the Gault rests with a marked surface of erosion on the Wealden Beds, we found only the common lamellibranchs which characterize the lower beds in the neighbouring sections to the west and at Holworth House. At both sides of the cove the exposures were poor and overgrown. A better section was seen further west at the east end of the bay at Dungy Head, east of Durdle Door. Here, again, we noticed the great rarity of ammonites and the general paucity of distinctive fossils in the lowest beds. The dark silty clay about 10 feet above the base yielded a few lamellibranchs, such as *Nucula pectinata* J. Sow., *Pecten* (*Syncyclonema*) *orbicularis* J. Sow., and *Lima* (*Mantellum*) *gaultina* Woods, as well as *Serpula concava* (J. Sow.), which is common in the *rostratus*-beds of Upper Greensand facies. Only one poor fragment of an ammonite was obtained, one of the species commonly designated *Hoplites splendens*, and apparently a form identical with one occurring in Bed IX at Folkestone and with the equivalent fauna at Heath, in Bedfordshire. At about 25 feet above the base, in a dark glauconitic clayey sand, we found numerous casts of lamellibranchs, including *Inoceramus sulcatus* Parkinson. So far as we were able to examine the beds above this point, there was agreement with the section as given by Professor Barrois. Lithologically and palæontologically, the silty and sandy Gault here forms a unit with the "Upper Greensand" above, into which it merges almost imperceptibly; and we see no reason to believe that the Lower Gault has any representation along this coast.

Near White Nothe, the overlap of the Gault on to Portland and Kimmeridge beds is displayed in a remarkable section.[1] We found the lowest bed of the transgressive strata to be a dark brownish green, gritty and clayey sand, containing pebbles of Portland limestone and quartzite at the base and showing ochreous weathering. The few feet of this bed yielded no fossils. The succeeding stratum, a soft, bluish silty micaceous clay, about 6 feet in thickness, seemed also to be almost barren of organic remains. Above this we were able to examine the beds at intervals upwards through a thickness of about 30 feet or rather more. In the lower part there occurred *Inoceramus concentricus* Parkinson. At higher levels there were numerous lamellibranchs, such as *Exogyra conica* J. de C. Sow. and species of *Panopea*, *Pinna*, *Pecten*, and the *Mantellum* mentioned above. This last species was conspicuously abundant, the valves attaining a large size in the upper part of these beds. There were also numerous crushed examples of a *Turritella*-like gastropod. The whole aspect of this fauna shows an approach to the facies of the Blackdown Greensand, of more markedly littoral character. Above this the section is obscured for some distance by talus. The succeeding beds of "Upper Greensand" type, yielding casts of ammonites of the *rostratus*-fauna, together with many lamellibranchs,

[1] A. Strahan, "The Geology of the Isle of Purbeck and Weymouth": *Mem. Geol. Surv.*, 1898, pp. 155–8.

have been accurately described by Sir A. Strahan (op. cit., p. 457). While visiting these coast-sections in Dorset we received much kind assistance from Capt. E. Gray.

Although the great rarity of ammonites and the development of a sandy facies in the Gault of this neighbourhood deprive us of the best criteria for correlation, we are of opinion that the *interruptus*-zone is unrepresented. The total absence of any of its distinctive faunal elements is alone a significant fact. This view is greatly strengthened by the occurrence of an isolated patch of *interruptus*-Gault bound up intimately, as usual, with the *mammillatus*-bed at its base, at Okeford Fitzpaine, in North Dorset.[1] At that spot there is displayed in some 8 feet of fossiliferous strata the familiar normal faunal type of the true lowest Gault Clay of other parts of this country, which is absent, however, at the base of the Gault where it rests unconformably upon the Kimmeridge Clay at neighbouring localities and throughout the northern part of the county. Light is thrown upon the matter by Mr. Newton's description of the section at one time well exposed at Okeford Fitzpaine, in which the upper part of the 19 feet of beds referred by him to the *interruptus*-zone is described as dark-grey, micaceous and sandy clay; and particularly by the fact that some of the fossils figured by him are Upper Gault and not Lower Gault shells (species of *Inoceramus* and *Trigonia*; large form of *Lima* (*Mantellum*) *gaultina* Woods). It seems clear that the *interruptus*-zone is there only represented by a thin local patch which has escaped denudation and is overlain by the transgressive Upper Gault, which alone is present in the neighbouring country to the north, just as in the coast-sections.

We have not yet been able to examine the Gault of Black Ven or its equivalents to the west. At Black Ven the Gault rests upon the Lias, and the assignment of its lowest beds to the Lower Gault by those who have described it is not supported by any evidence.[2] On the South Devon coast, near Seaton and Sidmouth, C. J. A. Meyer obtained *Inoceramus sulcatus* in his Bed 2, associated with a lamellibranch-fauna closely akin to that of the Blackdown Greensand.[3] Neither in this bed nor in the thin basal Bed 1 has there been found anything to suggest a Lower Gault age. At Blackdown and Haldon there is a closer approach to shore-conditions, with a sandy, shelly facies. No distinctive Lower Gault fossils have been found at these localities. The well-known fauna which comes in above the barren basal sands at Blackdown includes species of zonal value such as *Schloenbachia varicosa*, another *Schloenbachia*, well keeled, and

[1] R. B. Newton, "An Account of the Albian Fossils lately discovered at Okeford Fitzpaine, Dorset": *Proc. Dorset Nat. Hist. and Ant. Field Club*, vol. xviii, 1897, p. 66.

[2] A. J. Jukes-Browne, op. cit., p. 188. W. D. Lang, "The Zone of *Hoplites interruptus* (Bruguière) at Black Ven, Charmouth": GEOL. MAG., 1904, p. 124.

[3] C. J. A. Meyer, "On the Cretaceous Rocks of Beer Head and the adjacent Cliff-sections": *Quart. Journ. Geol. Soc.*, vol. xxx, 1874, p. 372.

Inoceramus sulcatus, which at Folkestone occur in Bed IX. *Inoceramus anglicus* Woods has been obtained at Haldon.

The silty and sandy beds constituting the lowest part of these westerly developments of the English Gault were probably accumulated with much greater rapidity than the more fossiliferous basal part of the Upper Gault clay in regions of deeper-water sedimentation. It is evident that the conditions under which they were laid down were unfavourable for cephalopod-life; and the general scarcity of fossils in the lowest beds may perhaps be taken to show that the extension of the sea-floor proceeded so rapidly that some time elapsed before faunal adjustments to the new conditions could be brought about. We have noticed elsewhere that when the character of the lowest beds of the transgressive Upper Gault is such as to point to their deposition in water rendered turbid by currents, fossils are scarce.

Oxfordshire, Buckinghamshire, and Bedfordshire.—We have not yet been able to visit sections showing the transgression of the Gault on to the Jurassic rocks which occurs in places in Wiltshire and Berkshire, and at Culham, in Oxfordshire. In Oxfordshire and Buckinghamshire an area of deeper water deposition is reached, where the formation attains a great thickness and the upper subdivision is largely developed in clayey facies. In this region the existence of an overlap of the Upper Gault is readily discernible. A nodule-bed which, at some localities in these counties and in Bedfordshire, occupies a position about 10 to 20 feet above the base of the Gault was formerly worked for "coprolites". The fossils obtained included typical species of the Upper Gault (Bed IX of Folkestone), showing clearly that the transgressive base of the Upper Gault occurred at those places at least as low in the series as at that level, if, indeed, Lower Gault was always present beneath. Failure to recognize the discordant relation of the Upper to the Lower Gault in this area gave rise to the appearance of an anomaly in the distribution of some of the fossils known elsewhere to be confined to the Upper Gault; they were here supposed to occur in the Lower Gault [1] because of their proximity to the base of the clay. The Lower Gault through a considerable part of this district is overstepped by the Upper Gault, which extends forward upon Wealden, Purbeck, Portland, or Kimmeridge beds, as the case may be.

An opening made by the Geological Survey in 1920 in a disused pit at Long Crendon, near Thame, on the margin of an outlier of Gault, showed 9 feet of Upper Gault with a well-defined basement-bed, 1 ft. 6 in. thick, of ochreous sandy clay with ironstone and other pebbles.[2] This rested upon a 2 ft. clay-band (Purbeck ?), underlain in turn by a Purbeck limestone. In the Gault Clay immediately

[1] A. J. Jukes-Browne, *The Cretaceous Rocks of Britain*, vol. i, "The Gault and Upper Greensand of England": *Mem. Geol. Surv.*, 1900, pp. 275 et seq.

[2] "Summary of Progress for 1920": *Mem. Geol. Surv.*, 1921, p. 62.

above its basement-bed we found *Inoceramus anglicus* Woods. Mr. S. S. Buckman has submitted to us a well-preserved fragment of *Schloenbachia varicosa* from the clay in an adjacent plot of ground. At a locality to the east of Thame station a well-sinking has recently shown us that there, too, the Gault rests on a Purbeck limestone. The overlap is also well seen in the neighbourhood of Aylesbury.

Just south of Leighton Buzzard the true Lower Gault crops out, the *interruptus*-clay here resting conformably, as usual, upon the *mammillatus*-bed, as first reported by Mr. G. W. Lamplugh. We have shown elsewhere that a special interest attaches to the series as here displayed. Owing to favourable conditions of preservation, the fauna of the *tardefurcata*-zone, situated immediately below the *mammillatus*-bed and characterized by species of *Leymeriella*,[1] is well represented within the 4 feet of sandy clay immediately underlying the *interruptus*-Gault and resting directly on the Lower Greensand. We have described in the paper just cited how, in the neighbourhood of Shenley Hill and Heath, north of Leighton Buzzard, the Upper Gault overlaps on to the Lower Greensand.[2] Since that description was published we have made further visits to those sections, as well as to others in the vicinity, and have fully confirmed our previous observations as to the inverted order of zones in the transported masses of Cenomanian limestone and Upper Gault clay at Shenley Hill. As regards the overlapping Upper Gault, further information has been obtained in two exposures near Heath and in a small opening south-east of Shenley House. The basement-bed of ochreous sandy clay, with grit grains, pebbles, and fragments of ironstone, is here succeeded, as before described, by sparsely fossiliferous, poorly bedded clay-breccia composed of small fragments and pellets of clay of varying colour and texture. This passes upwards into more evenly bedded and slightly silty clay containing *Terebratulæ*, *Inoceramus concentricus* Park., and fish-scales, overlain in turn by paler Gault with *Inoceramus sulcatus* (common) and ammonites of the *rostratus*-fauna, chiefly in a phosphatic bed.

At Clophill, near Ampthill, the *interruptus*-Gault is again seen at the outcrop, with the *mammillatus*-zone below it. At Biggleswade the same beds were found in a well-sinking below Boulder Clay, on which rests the remarkable transported mass of Ampthill Clay described in 1903 by Mr. H. Home.[3]

Norfolk.—North-east of Cambridge the Gault, which is poorly exposed, disappears beneath the alluvium of the Fenland east of Ely and does not reappear until the neighbourhood of West Dereham is reached. Nothing was known of the characters of the formation where it is concealed beneath the Fens until recently, when several

[1] F. L. Kitchin & J. Pringle, GEOL. MAG., Vol. LVII, 1920, pp. 52, 53.

[2] See also F. L. Kitchin & J. Pringle, "Excursion to Leighton Buzzard": *Proc. Geol. Assoc.*, vol. xxxii, 1921, p. 173.

[3] *Quart. Journ. Geol. Soc.*, vol. lix, p. 375.

borings proved the Upper Gault to rest on the basal bed of the Sandringham Sands. This points to considerable erosion of the Lower Greensand prior to the deposition of the transgressive clays. At West Dereham and Mouse Hall ("Muzzle"), only a few miles to the north, a thin representative of the *interruptus*-zone, not more than 3 feet thick at Mouse Hall, rests directly upon the sandy *mammillatus*-bed. At both localities we have obtained the typical fossils of these two horizons. At Mouse Hall this remnant of the *interruptus*-zone is overlain by very pale Upper Gault Clay, which was at one time mistaken for Chalk Marl. This clay yields *Inoceramus sulcatus* Park. and other fossils of the Upper Gault in its lowest part. It is evident that the base of the overlapping Upper Gault here rests upon a thin remnant of the Lower Gault which has locally not been wholly removed by the erosion accompanying the overlap. These appear to be the most northerly exposures of the Lower Gault known in this country.

North of West Dereham the Upper Gault thins rapidly and becomes highly calcareous. Few good exposures are to be seen until the neighbourhood of Grimston is reached, some 14 miles to the north. Here the characteristic fauna of Bed IX of Folkestone is found a few feet above the base of the overlapping strata, which rest on unfossiliferous Lower Greensand.[1] At Dersingham the Upper Gault is reduced to 7 feet in thickness and there shows increasing hardness and the introduction of the red coloration which becomes so characteristic at Snettisham and Hunstanton to the north. It becomes evident now that we are dealing with a thin calcareous equivalent of the overlapping argillaceous Upper Gault. The remarkable reduction in the thickness of the Upper Gault may be seen by a comparison of a series of well-sinkings and borings between Stoke Ferry and Snettisham. Within this distance there is a reduction in thickness from 56 feet at Stoke Ferry to 3 ft. 6 in. at Snettisham.

(To be continued.)

The Northward and Eastward Extension of the Karroo Lavas.

By F. P. Mennell, F.G.S., M.I.M.M.

THE lavas which cap the Karroo beds of Southern Africa have general interest as indicating the eruptive activity prevailing at a time of complete quiescence in the European area. The sedimentaries immediately beneath them (Stormberg series) are of Rhætic or even Liassic age, so that the lavas themselves, which are many thousands of feet thick in the Drakensberg range, may confidently be ascribed to the Jurassic period.

[1] W. Hill & A. J. Jukes-Browne, "On the Lower Part of the Upper Cretaceous Series in West Suffolk and Norfolk": *Quart. Journ. Geol. Soc.*, vol. xliii, 1887, p. 551.

During the last two years the writer has made a number of journeys through Northern Rhodesia and Portuguese East Africa, one of the results of which has been to show that the lavas of this period have an extension considerably further northward and eastward than has been generally recognized. This is not to say that the volcanic rocks themselves have escaped notice—though even this appears to be the case with the first area to be dealt with—but their age has not been determined. Hence a few notes on the occurrences may not be out of place, though these are necessarily brief, as constant travelling has prevented any detailed petrographical investigation of the features the rocks present.

Northern Area.

From the railway bridge crossing the Kafue River in Northern Rhodesia, some 250 miles north of the Zambesi bridge at the Victoria Falls, there can be seen almost due east some hills in which the discerning eye will detect distinct indications of a synclinal structure. The only doubts arising as to the reality of this arrangement are due to the fact that the whole area round about is one of Archæan rocks. However, a journey of about 10 miles across the Kafue Flats enables this point to be settled, and the stratified arrangement of the rocks becomes clearer as the hills are approached. It is probable, indeed, that a strip of sediments really underlies the alluvium of the flats almost up the bridge itself, but it is not till in the immediate neighbourhood of the hills that any unmistakeable signs of them are seen, in the shape of a few feet of soft reddish sandstone in the bank of a small stream. It may at once be said, however, that the hills themselves, which are 600 or 700 feet high, are entirely volcanic, and the well-marked step-like appearance they present when seen from the south indicates that they consist of six or seven distinct flows, the number adopted depending on whether the faintly marked ridge stretching out from beneath the last of the much steeper scarps above is basalt or the top of the sandstone, a point which had to be left undecided. Water-level in the Kafue is about 3,200 feet above the sea, so that the tops of the hills must reach to nearly 4,000 feet, the western edge already referred to not being quite the highest point.

An examination of the area showed that the lavas, etc., extend for 10 miles or more east of their first conspicuous outcrops, and probably form a complete basin elongated in that direction. Both north and south they are flanked by much more irregular slopes of the ancient gneisses and schists which emerge from beneath them. Whether there is any faulting round the margins of the younger rocks cannot be definitely decided in the absence of any clear sections of the junction, but though suspicions were entertained that such might be the case, the conclusion was eventually reached, after close investigation, that the base of the sediments rested directly upon the ancient schists and gneisses. These sediments consist of sandstones

having a total thickness of about 150 feet, of which the uppermost 50 feet are fine and rather crumbly, while the lower 100 feet are harder, more uniform and coarser in grain, and are characterized by the presence of small scattered pebbles. They are, in fact, identical in every respect with the "Escarpment Grits" of the Wankie coalfield further south, and of the intervening areas of Coal Measures, of which the nearest is within about 20 miles. The fact that no more than 50 feet of strata are lithologically similar to the fine-grained Forest Sandstones, which are many hundreds of feet thick elsewhere, is surprising, especially as they rest with apparent conformity on the Escarpment Grits, but it is in line with the remarkable divergences seen among the Karroo strata as they are followed eastward towards the coast.

The lavas, of which the flows, as already noted, average about 100 feet in thickness, are uniformly basalts of the same type as seen at the Victoria Falls. They are highly amygdaloidal at the base and summit of each flow, and the amygdales as usual contain many zeolites. Towards the eastern end of the basin the Kesha River cuts through these rocks at a point where only two flows survive, and its bed is in the Escarpment Grit until it gets on to the gneisses, across which it makes its way into the Kafue, some miles to the north. From the position of the block of basalts, etc., it seems clear that the Kafue has just finished the removal by erosion of a great area of basaltic lavas like those of the Victoria Falls, after first cutting a gorge through them like that of the Zambesi, at the head of which similar falls must at one time have existed. It is also evident that the Kafue, like the Zambesi, had its course largely determined by synclinal structures in the Karroo rocks. Although the Karroo rocks are often much faulted, the faulting has had no direct bearing on the position of these rivers; indeed, not far away, at the Kariba Gorge, the Zambesi is in the ancient gneisses and schists, on the upthrow side of a series of seven step faults which successively bring up the Archæan rocks against the Karroo strata. It is hoped to describe the structure of this interesting area at a subsequent date.

Eastern Areas.

I. *Tete.*—The presence of Coal Measures (i.e. Lower Karroo beds) at Tete, on the Zambesi, in Portuguese East Africa, has long been known, and igneous rocks have been recorded from the same area. It is quite possible that the occurrence of the lavas has also been recorded, though I have not seen any distinct reference to them myself, the volcanics to which reference is generally made being the dolerite intrusions which are extremely numerous in the Tete district. This latter fact is remarkable, as in Northern and Southern Rhodesia no dyke traversing the Karroo strata has yet been definitely identified. The lavas to which I refer are situated a few miles above the Lupata Gorge, and must be clearly distinguished from the volcanic rocks of the gorge itself. The Karroo lavas are, as usual,

basalts and are probably anything from 500 to 1,000 feet in thickness. They have a gentle easterly dip, and the directly underlying rocks are very badly exposed; in fact, the sandstones seen to the west are on a horizon which is probably at least 500 or 600 feet below the base of the flows. They are nearly white felspathic grits, extremely similar to the Upper Sandstones of the Wankie Coalfield in Southern Rhodesia, but they clearly belong to a higher stratigraphical horizon, as they are certainly 1,000 feet above the Coal Shales. Above the basalts are sandstones of an entirely different character, very like some of the New Red rocks in England. They are no doubt of Jurassic age, and are about 1,200 feet thick, being succeeded by the Lupata Volcanics, which must be of Lower Cretaceous age, if, indeed, they do not reach down into the Jurassic period. It should be noted that the isolated sheet of columnar rhyolite which caps the magnificent scarp at the entrance to the gorge divides the sandstones almost equally into two divisions. These may be termed the Upper and Lower Lupata Sandstones for convenient reference. They are very varied in character, ranging from coarse conglomeratic varieties to what may be termed "marls", but are chiefly coarse to medium sandstones red, purple, brown, yellow, or even occasionally white in colour. The Lupata Volcanics are entirely different from any of the Karroo lavas. As a field term "felspar-porphyry" may be applied to most of the varieties, but some of the rocks are rhyolitic, while others contain large porphyritic nepheline crystals (often represented on weathered surfaces by cavities), and at two localities specimens were secured which contain numerous porphyritic crystals which must be leucite or pseudomorphs after that mineral. Tuffs and agglomerates occur at intervals and also seams of tufaceous sandstone. The volcanics are overlain by the Cretaceous sandstones, which often show pebbles of the characteristic Lupata Volcanics, and are themselves succeeded on the Sheringoma plateau by limestones containing numerous fossils which range from Late Tertiary to Upper Cretaceous age. The thickness of all these strata is very great, and it is hoped to describe them in more detail when the petrographical and palæontological collections are worked up. They are referred to chiefly to emphasize the fact that to attribute all the nepheline-bearing rocks of East Africa to the Tertiary period is clearly erroneous, as the Lupata Volcanics cannot by any possibility be higher up in the stratigraphical scale than Lower Cretaceous. No faulting can be invoked to invalidate the stratigraphical evidence, owing to the fortunate fact that, as already mentioned, the overlying Cretaceous rocks contain pebbles derived from the volcanics adjacent to them.

II. *Maringwe Area.*—If the inland district of Maringwe be approached from the north side, i.e. from the Zambesi, or from the east, as, for instance, from Inyaminga, the gently inclined Cretaceous sandstones of Sena in the one case, or the Tertiary limestones in the other, are gradually found to give way to older and older sediments

until near the Barue border a series of basaltic lavas are met with emerging from beneath them. Messrs. Teale and Wilson long ago referred to these, but though they do not definitely correlate them with the Lupata Volcanics, they were evidently disposed to do so. As a matter of fact, the Lupata Volcanics die out in a most remarkable way only about 20 miles south of the Zambesi, as indicated by the disappearance of the marked feature they make when looking across country. Their position is, however, clearly indicated in the course of the traverses referred to by the sudden disappearance of the pebbles derived from them, which are very conspicuous in the Cretaceous beds, but are, of course, absent from the Lupata sandstones. An extensive area of these is crossed before reaching the basalts, which emerge from beneath them with a gentle easterly dip, a fact which places their age beyond question and is entirely confirmed by their lithological character, even though they are of more varied types than usual. They form a belt about 7 or 8 miles across, partly flat country, but their western edge rises into a scarp several hundred feet in height, breached by several rivers, of which the Hata affords a particularly good section. The number of flows is evidently considerable and the thickness of the series greater than at Tete, while much more variety is seen in the colour, texture, etc., of the lavas. There are masses and beds of agglomerate at several points; some of the former no doubt indicate vents. The volcanics must stretch a hundred miles from north to south; their southern termination appears to be near the great mountain mass of Gorongoza, and northward they may even connect with those of the Tete area. Inside the Barue boundary the underlying sandstones are well seen, an interesting point, as they are completely obscured by alluvium near the Lupata Gorge. They are very varied in character, a common type being arkose-like, with pink felspars. A single narrow band is fine-grained, and pale-buff in colour; this is the only stratum seen at all reminiscent of the Forest Sandstones of Rhodesia. A feature of the locality is the large number of dolerite dykes by which the sandstones are intersected and the remarkable metamorphism of the latter in their vicinity. These are frequently converted into rocks indistinguishable in the field from a pinkish granite, for which they were indeed mistaken until clearly seen *in situ*.

On Lower Lias Ammonites from Skye.

By Dr. L. F. Spath.

THE writer has thought it desirable, in the following observations, to embody the results of his examination, last September, of the *Arnioceras*-bearing beds of Ardnish, near Broadford in Skye. The strata yielded a number of Ammonites of the Upper *Coroniceras*, *gmuendensis*, and *Ætomoceras* subzones, and belong chiefly to the "Shaly Beds" of division iv of the Broadford Beds of the Survey

Memoir on "The Geology of Glenelg, Lochalsh, and the South-East Part of Skye" (1910). They are therein referred, as by Professor Judd in his well-known paper on "The Secondary Rocks of Scotland", to the *bucklandi* and *semicostatus* zones. Judd, the founder of the zone of *A. semicostatus*, certainly, however, misidentified some of his Ammonites, besides confusing his Lincolnshire *A. geometricus* with Young and Bird's *A. semicostatus* of a much higher horizon. Similarly, the Rev. J. E. Cross, in his paper on the "Geology of North-West Lincolnshire" (Q.J.G.S., vol. xxxi, 1875), recorded *A. semicostatus* from both the lower *Gryphæa incurva* beds and the higher Scunthorpe Ironstone, which presents close analogy with the *gmuendensis-Ætomoceras-Agassiceras* beds of the Harzburg Ironstone. In reality this Ammonite (*Arnioceras semicostatum*) occurs in a much higher zone than either of these Lincolnshire beds.

The well-known extended range of "*Arnioceras*" and the difficulty of distinguishing the various species of this genus have generally frustrated attempts at a correlation of *Arnioceras*-bearing beds in different areas. It may be mentioned here, for example, that Quenstedt, in his "Ammoniten des schwäbischen Jura", figures only one and a very obscure "species" of *Arnioceras* (*A. falcaries olifex*) from beds that, in Dorset, can be subdivided into about six subzones. Through the kindness of Dr. W. D. Lang, the writer has been able to study the Ammonite fauna of these 53 feet of *Arnioceras*-bearing strata (Nos. 53–74) at Charmouth, and it is important to note that these beds (*Agassiceras* and higher zones) are later than any of the Skye strata here dealt with. Apparently, however, even the Dorset forms of *Arnioceras*, collected by Dr. Lang, do not include examples from the true *semicostatus* bed. This the writer believes to be in the *birchi* subzone, though, as yet, not found in place. The Survey, it may be noted, had placed the whole of these beds 53–74 above the *semicostatus* zone. It should be added that specimens of *Xipheroceras* cf. *capricornoides* (Quenstedt), in the British Museum, have been found attached to two slabs of this Dorset *semicostatus* bed, and that Professor Blake already noted the occurrence of his *A. nigrum*, which, like *A. flavum* and *A. anageneticum*, S. Buckman, is a constant companion of *A. semicostatum*, with *Am. birchi*. The description of the Dorset material (Part ii, "Notes on the Ammonites" in Lang, Spath and Richardson: "Shales-with-Beef, a Sequence in the Lower Lias of the Dorset Coast," Proc. Geol. Soc., No. 1,079, January 13, 1922, p. 30) contains the major details of these higher beds, but it will be seen that Judd's "Zone of *A. semicostatus*" must be abandoned, for, like Wright's "Zone of *Arietites turneri*", it was based on a misidentification.

The Broadford Beds here dealt with include the *Ætomoceras* and *gmuendensis* subzones, with possibly the Upper *Coroniceras* subzone below, but neither the three lower subzones (*bucklandi, rotiforme,*

and *conybeari*) nor the uppermost (*Agassiceras*) subzone of Oppel's original "*Bucklandi*-Bett" seem to be represented by ammonitiferous deposits. In Raasay, however, *Arnioceras* occurs above beds with *Agassiceras sauzeanum*, and at Mingary Castle in Ardnamurchan, Argyllshire, the higher beds with *Agassiceras* and probably also the *Pararnioceras* zone are developed, the latter being equivalent to Oppel's *tuberculatus* zone (with *P. compressaries* and *P. nodosaries*, Quenstedt sp., as characteristic Ammonites), and to Wright's wrongly named *turneri* zone, also originally proposed for the "Pentacrinite Bed". Still higher beds at Mingary Castle include *Arietites*, and though it might be inferred from certain passages in Oppel and Quenstedt that the *Pentacrinus* bed (= *tuberculatus* zone) should include the *birchi* subzone, yet these higher *Arietites* and *birchi* beds are rather to be considered as belonging to the *obtusus* zone, which thus is divisible into at least ten subzones. Beds with *Asteroceras smithi* and *Xipheroceras ziphus, planicosta*, and *dudressieri* on the western side of Broadford Bay, north of Corry, could not be connected with the highest beds of Ardnish to the east. They consist of the same metamorphic micaceous rock with the Ammonites coated with blue vivianite. But among a few of these Ammonites of the *Asteroceras* and *Xipheroceras* types from the western side of Broadford Bay, collected by Mr. J. Phemister and submitted to the writer through the kindness of Professor Gregory, there was an example of a late *Arnioceras* ("*Eparnioceras*") comparable to *A. semicostatum* (Young and Bird) Fucini, indicating the probable presence of the *birchi* zone below the beds with *Xipheroceras*.

It might be mentioned that the Survey Memoir records a form "near to *Asteroceras brook(e)i*", apparently from between Sgiabain and Achadh a' Chuirn; but this may, perhaps, be a form similar to the *Paracoroniceras* sp. of the *gmuendense*-group recorded below from 15 inches above the *isis* bed at R 2.[1] The writer has found no evidence for any post-*scipionianus* beds on the eastern side of the bay, and there is thus a considerable stratigraphical gap between them and the beds on the western side, north of Corry.

The thicknesses given in the following pages are approximate. The Survey consider division iv to be exposed to at least 125 feet. The writer has not been able to make out anywhere a continuous succession of more than perhaps 40 feet. The repetition of, e.g., the *acuticarinatus* bed, with the cutting up of the beds by numerous dykes and the occasional occurrence of more highly metamorphosed beds with unrecognizable Ammonites, make the tracing of the true succession very difficult. Moreover, the strike coincides practically with the trend of the coast-line.

The succession is as follows, Beds R 4 to R 1 being to the south-

[1] In the Alps a development with somewhat similar outer whorl (PSEUDASTEROCERAS, gen. nov., type *A. stelliformis*, Gümbel in Waehner, v, 1888, pl. xlv, fig. 2) occurs already in Lias α 3–4, just above the *marmorea* zone.

west of, but near to, the point Rudh' Achadh a' Chuirn (R), beds A to A 8 to the north-east of the point, on the Ardnish shore.

R 4. Beds below *Gryphæa* reefs, roadway from Sgiabain (Waterloo) to point R, near last houses :—

Epammonites cf. *latisulcatus* (Quenstedt) Schmidt.

The new genus EPAMMONITES is proposed for *Arietites latisulcatus* (Quenstedt) Schmidt ("Die Arieten des Unt. Lias v. Harzburg," *Palaeontogr.*, vol. lxi, 1914, p. 22, pl. iv, fig. 1), and includes e.g. *E. parthenope*, *E. isis*, Reynès sp., and *E. compressaries* (Reynès non Quenstedt). It is interpreted as a development parallel with the contemporaneous true large *Arnioceras* of the *ceratitoides* group, belonging to the Upper *Coroniceras* and *gmuendensis* zones. *E.? paolinæ*, Reynès sp., connects the new genus both with *Arnioceras* and the ancestral *Ammonites*, Bruguière (here restricted to the group of *A. bisulcatus*, Bruguière in d'Orbigny, Pal. Franç., Ter. Jurass., pl. xliii). *Epammonites* retains evolute whorls, but does not acquire the stiff costation of *Arnioceras*. PARACORONICERAS, gen. nov., established for the group of *A. gmuendensis*, Oppel (Reynès, Monogr. d. Ammon., 1879, pl. xvi, figs. 1, 2), though belonging to a closely allied stock, tends to trigonal whorl-shape and involution.

R 3. *Gryphæa* beds, 12–20 feet (estimated vertical distance) below R, yielded no Ammonites.

R 2. Ammonitiferous shales, 6–10 feet below R and to the south-west of the dyke at the point. *Arnioceras* spp. are recorded from here by the Survey ; the less well-preserved examples of the forms quoted below greatly resemble *Arnioceras*.

Epammonites aff. *isis* (Reynès).
,, sp. n. aff. *isis* (Reynès).
,, aff. *schloenbachi* (Reynès).

At about the same horizon were found :—

Paracoroniceras cf. *crossi* (Wright).
Ætomoceras scipionianum (Orbigny).
,, aff. *personatum* (Simpson).
,, PSEUDOSTRIARIES sp. nov.

The last is a flattened *personatus*-like form, with obscurely sulcicarinate periphery and faint but close costation. The exact bed containing these forms was not noted.

R 1. A fragment of *Paracoroniceras* sp., apparently of the *gmuendense* group, was found 15 inches above the *isis* bed, i.e. about 5 to 9 feet below R. It is thus impossible to state whether these higher beds belong to the *scipionianus* or the *gmuendensis* zone. This is the *brooki*-like fragment referred to before.

R. Dyke at the point, highest level.

Ax 2. Reefs of micaceous shales, 10–12 feet below level R, on the north-east side, beyond the last house :—

Ætomoceras scipionianum (Orbigny).
Arnioceras cf. *acuticarinatum* (Simpson).

Ax 1. Dykes at M on map, 3 feet above Ax.
Ætomoceras scipionianum (Orbigny).

Ax 1′. One foot above Ax, same species.

Ax. *Acuticarinatus* bed, with numerous examples of *Arnioceras acuticarinatum* (Simpson) and allied species, and :—
Ætomoceras cf. *resupinatum* (Simpson).
,, sp. nov. ?
,, aff. *personatum* (Simpson).
,, *scipionianum* (Orb.) incl. several var.
,, sp. nov. ? (a flatter form).
,, sp. nov. ? (densely costate, thick).
,, cf. *nodulatum*, S. Buckman.
,, *scipionianum*, var. *spinaries* (Quenst. non Hyatt).
Paracoroniceras ? sp. (like '*brooki*' fragment aforementioned).
Arnioceras ? cf. *angusticostatum*, Tilmann.
Epammonites cf. *isis* (Reynès).
,, cf. *parthenope* (Reynès).
,, ? cf. *arnouldi* (Dumortier V non VI).

The last was found in a weathered-out condition, but probably also came from these elevated reefs. The beds Ax are shown in the 1 in. geological map (sheet 71) just south of the letter M denoting numerous dolerite and basalt dykes and sills.

AxO. Ledges 1 foot and 1 ft. 6 in. below Ax :—
Ætomoceras scipionianum (Orbigny).

Ao. *Gryphæa* bed I, 4 to 6 feet below the *acuticarinatus* bed ; large impressions of the same Ammonite still occurred.

Aó′. Six feet of ledges with Ammonites scarcer, badly preserved, and doubtfully identified as
Epammonites cf. *isis* (Reynès).
,, cf. *schloenbachi* (Reynès).
Arnioceras cf. *geometricum* (Oppel) Schmidt.

Ao″. *Gryphæa* bed II, 6 feet below first one, containing one large, crushed fragment of
Paracoroniceras gmuendense ? (Oppel).

A 1. "*Coroniceras*" bed, 6 feet below last, without recognizable Ammonites in between.
Paracoroniceras sp. ind.?
Epammonites sp. ? (cf. *paolinæ*, Reynès, and *deffneri*, Oppel).
MEGARIETITES [1] sp. ind. ? (last not "in place").

The Survey recorded *Coroniceras lyra* from east-north-east of Rudh' Achadh a' Chuirn, and the forms found in A 1 were thought, when first seen, to belong to Hyatt's species-group ; but it is to be noted that similar *Epammonites* occur in the highest beds.

[1] Gen. nov., genotype *A. meridionalis*, Reynès, loc. cit., 1879, pl. xxii, figs. 1–3.

A 2. *Cardinia* beds, several feet. The strata become brown and sandy, less metamorphosed, and continue in flat ledges to another dyke. The Ammonites of the *Cardinia* beds, namely,

Arnioceras cf. *geometricum* (Oppel),
,, cf. *ceratitoides* (Quenstedt),

are poorly preserved.

A 2′. Just beyond the dyke

Paracoroniceras sp.?

was found, then the lowest beds are exposed. These are apparently above the *Cardinia* beds on the other side of the dyke, and it is thus probable that the dyke intruded along a fault plane. On the island of Pabay (Pabba), the Liassic succession of which the writer studied and hopes to describe shortly, faulted dykes are also apparently numerous. In an ascending sequence, fairly high beds follow again soon.

A 3. Bed full of *Arnioceras*, namely :—

Arnioceras aff. *falcaries* (Quenstedt).
,, cf. *spirale*, Fucini.
,, cf. *repens*, Fucini.
,, cf. *kridioides*, Fucini non Hyatt ?
,, sp. nov. aff. *acuticarinatum* (Simpson).
,, sp. (aff. ? *A. bucklandi*, Reynès xxi/4, non Sow.).

A 3′. Six feet above A 3 the *acuticarinatus* bed first seen at Ax was again recognized, containing also :—

Ætomoceras scipionianum (Orbigny).
,, cf. *personatum* (Simpson).

A 4. Near the high point on the shore, north of the letter *n* in Ardnish on the 1 in. map, a dyke again interrupts the succession, but beyond, i.e. to the north-east, apparently similar beds occur, containing :—

Nautilus striatus (Sowerby),
Ætomoceras scipionianum (Orbigny),
,, spp. ind.,

in addition to *Arnioceras*, like those of the *acuticarinatus* beds and impressions of large examples probably of *Ætomoceras* 2 feet and more in diameter.

A 5. A *Gryphæa* bed follows, perhaps 8–10 feet below horizon A 4, and a second one :—

A 5′, probably about the same distance below A 5, succeeds the first, whereas 5 feet lower still, or perhaps some 20–25 feet below A 4, at

A 6, *Epammonites* cf. *latisulcatus* (Quenstedt) Schmidt

was found, closely similar to the example from south-west of the point R. This probably is the same horizon as at A 1, about 20 feet below the *acuticarinatus-scipionianus* bed, i.e. the horizon of the so-called "*Coroniceras* bed". Judging by the presence of large Ammonites of the *gmuendense* zone (group of *Paracoroniceras crossi*, Wright sp.), it seems probable

that the succession at this point is still above the true *bucklandi* hemera.

Further to the north-east, nearer the point Rudha Ardnish, the same *Arnioceras*-bearing beds occur, the high *acuticarinatus* bed with *Ætomoceras scipionianum* coming up again at least once more at

A 7, with the Ammonite species found at Ax and at A 4.

Finally, greenish-white fucoid shales and sandstones come in near Ardnish Point, containing

A 8, ARNIOCERATOIDES (gen. nov.) *kridion* (Hehl) Zieten sp.

These beds probably belong to division iii of the Survey, and seem to be the lowest beds in the succession, perhaps ranging as low as the true *bucklandi* beds; but it is significant that no *Coroniceras* (*coronaries* group), *Ammonites* s.s. (*bisulcatus* group), EUCORONICERAS, gen. nov. (type *A. sinemuriensis*, Orbigny, l.c., pl. xcv, figs. 1–3), or *Megarietites* were discovered anywhere along the shores of Ardnish.

The true *bucklandi* beds, however, seem to be developed in Morvern (Loch Aline) and Mull (Craignure), though at the latter locality only a fragment of a large *Schlotheimia* cf. *thalassica* (Quenstedt) was discovered. The higher *Arnioceras* beds, farther east, towards Duart Bay, again wrongly referred to the *semicostatus* beds by Judd, apparently agree with those in the *gmuendense* and *scipionianum* zones of Ardnish, but they are strongly metamorphosed and the Ammonites are scarcely recognizable.

The writer tenders his hearty thanks to all those who with material or otherwise have helped him in the preparation of this paper.

REVIEWS.

THE CRINOIDEA FLEXIBILIA. By FRANK SPRINGER. 4to, vi + 486 pp., 79 plates. Smithsonian Institution, Publication 2,501. Washington, 1920.

SINCE the publication of the monograph on the Crinoidea Camerata and the death of its senior author, Charles Wachsmuth, in 1896, Mr. Springer has devoted the leisure of a busy life to the study of another Order of the Crinoidea—the Flexibilia. The result is presented in these handsome volumes, for which gratitude on our part is more becoming than praise. This monograph differs from its predecessor in that it treats of all the known species from whatever part of the world they come. To attain this comprehensiveness Mr. Springer has drawn upon an unusually large number of public and private collections, and by employing collectors in the field has added much new and interesting material to his own collection, housed in the United States National Museum. Those individuals and institutions who have confided their treasures, and in some cases their notes, to Mr. Springer for publication must feel proud that they have contributed to so magnificent an edifice, and must realize how far more they have advanced science than they could have done by impatiently forestalling his labours. Doubtless they knew that they were in safe hands. Mr. Springer has, in fact, given them the fullest credit, and, as type-specimens of species newly described from other countries, he has selected, where possible, specimens in the respective national museums.

All this exploration was necessary because the Flexibilia are the rarest of crinoids. Specimens were almost unknown to the early writers, even down to Johannes Müller, and when they became known their nature was at first little understood. The reason, apart from rarity, is that the Order is a peculiar one. While some genera, such as *Sagenocrinus*, superficially resemble the Camerata, others, such as *Lecanocrinus*, can be distinguished only with difficulty from the Inadunata. The former resemblance, such as it is, is due to convergence; the latter proves, as suggested in 1900, to be the expression of relationship, for *Lecanocrinus* is connected, through *Protaxocrinus* and *Cupulocrinus* of the Lower Trenton, with the Dendrocrinidæ. Moreover, the diagnostic characters of the Order are obscure: the finely plated skin, by which the arms in some genera were loosely joined, has generally disappeared from the fossils; the open mouth is invisible in all but the rarest specimens; the loose union of the skeletal elements is a feature more readily appreciated by the experienced eye than described in good set terms.

Here, however, we cannot pause to discuss those questions of anatomy and affinity so admirably dealt with by Mr. Springer. The most useful employment of allotted space will be to give a

List of the British Species of Flexibilia as they result from his profound researches :—

Lecanocrinus bacchus (Salter sub *Ichthyocrinus*)	Wenlock.
Homalocrinus parabasalis Angelin . . .	,,
Synn. *Taxocrinus nanus* Salter MS. *Homalocrinus dudleyensis* Springer.	
Calpiocrinus intermedius Springer . . .	,,
Hormocrinus anglicus Springer . . .	,,
Pycnosaccus bucephalus (Bather sub *Oncocrinus*)	,,
Temnocrinus tuberculatus (Miller sub *Cyathocrinites*) (usually known as *Taxocrinus*) .	,,
Meristocrinus orbignyi (M'Coy sub *Taxocrinus*).	Upper Ludlow.
Meristocrinus minor Springer . . .	Wenlock.
Sagenocrinus expansus (Phillips sub *Actinocrinites*)	,,
Ichthyocrinus pyriformis (Phillips sub *Cyathocrinites*)	,,
Ichthyocrinus intermedius Angelin . . .	,,
Ichthyocrinus phillipsianus Springer . .	,,
Eurycrinus concavus Phillips. . . .	Lr. Carboniferous.
Eurycrinus rofei Bather & Gregory in Springer	,,
? *Eurycrinus granulosus* Phillips (sub *Poteriocrinus*)	,,
Wachsmuthicrinus ponderosus Springer . .	,,
Synerocrinus incurvus (Trautschold) . .	,,
Amphicrinus scoticus Springer . . .	,,
Taxocrinus macrodactylus Phillips . . .	Upper Devonian.
Taxocrinus stultus Whidborne . . .	,,
Taxocrinus nobilis (Phillips sub *Peteriocrinus*) .	Lr. Carboniferous.
Onychocrinus wrighti Springer . . .	,,
? *Onychocrinus polydactylus* (M'Coy sub *Taxocrinus*)	,,

F. A. Bather.

The Geology of the Country surrounding Johannesburg. By E. T. Mellor. Explanation of Sheet 52, Geological Survey of the Union of South Africa. pp. 46, with colour-printed map, 1921. Price, including map, 5s.

The well-printed map on the scale of 2·347 miles to the inch covers an area of about 2,100 square miles, with Johannesburg approximately at its centre. A comparison of this map with that on a slightly smaller scale published by Dr. Hatch in 1903, serves chiefly to emphasize the remarkable accuracy of Dr. Hatch's pioneer work. The chief difference to be discerned in the new map is a considerable extension of the Coal Measures in the eastern district between Benoni, Springs, and Heidelberg, and the introduction of some considerable patches of Karroo dolerites overlying the Dolomite north-west of Heidelberg. Another new feature of minor importance is a

curious basin of dolomite on Vogelstruisfontein, south of Roodepoort. It is considered that the Elsburg beds are perfectly conformable to the Upper Witwatersrand series, but indicate a gradual overlap of the last-named over the Lower Witwatersrand. The name of Transvaal System for the Black Reef-Dolomite-Pretoria series must now be regarded as standardized, in place of Potchefstroom System formerly used by Hatch and Corstorphine, but there appears to be no particular reason for its adoption.

The memoir gives an admirably clear account of the physiography and geology of this interesting and important area, bringing out all the salient features. Only one page is devoted to the gold-reefs, and the general geological reader unacquainted with the district would not acquire a very clear idea of their features and extent. There is singularly little reference to the highly important East Rand area, which lies just on the eastern margin of the map.

The memoir concludes with an excellent chapter by Dr. du Toit on the underground sources of water-supply in the Dolomite.

R. H. R.

Imperial Institute: Monographs on Mineral Resources with Special Reference to the British Empire: Oil-Shales. By H. B. Cronshaw, B.A., Ph.D. pp. x + 80. London: John Murray. 1921. Price 5*s.* net.

THIS volume is a companion to the recent memoir on petroleum by the same author, and it combines that lucidity of exposition with summary treatment characteristic of the earlier work. Latterly public interest has been directed to the problems facing an increased demand for and decreased supply of natural petroleum, and while the ultimate location and opening up of new oilfields must necessarily form one of the chief solutions, mitigating circumstances will also be found in the development of the world's oil shale resources, which may, without exaggeration, be regarded as prodigious. In America the possibilities of the oil shale industry have long been recognized though little progress seems to have been made, while in this country, although in the Midlothian occurrences we recognize the pioneer field, comparatively little heed had been paid to its development until the war caused a focus of attention on national resources. In 1920 the American industry received an impetus from the researches and publications emanating from the Colorado School of Mines, and Alderson's well-known "Oil Shale Industry" created a favourable atmosphere for a wider consideration of the possibilities of oil production from shales and torbanites. A statement of the world's resources of such raw material was the natural sequel to this, and the publication of the present memoir is therefore a further step in the right direction.

The sources of supply of oil shale are dealt with under the headings of British Empire and Foreign countries; the former comprises the occurrences in the British Isles, South Africa, Canada, and

Australasia, the latter those of Europe, certain countries in Asia, Morocco, the United States, Brazil, Chile, and Uruguay. In Scotland the shale industry has had a somewhat chequered career, being influenced in the past by the extent of importation of crude oil and sodium nitrate from the New World; the war failed to stabilize the industry as anticipated, and latterly decline has been rapid, largely due to abnormal economic conditions, and not, as frequently stated, to the exhaustion of raw material. The recent amalgamation of the companies concerned and their union with one of the premier oil companies have preserved the industry from extinction, the intention being to satisfy the capacity of the refineries by supplementing with crude oil from extraneous sources. The Norfolk shale field is in process of development, and a concise account of the occurrence and of the products obtainable from the shale is given here. Other prospects in the British Isles are not very hopeful. In South Africa, the Wakkerstroom district is being actively exploited at the moment, a test yield of 31 gallons of oil per ton of shale from one locality being an encouraging feature. Mennell has frequently reported on the Rhodesian resources of oil shale, while in Canada the Mackenzie River region offers possibilities in this connexion in addition to its crude oil potentialities. New South Wales is the largest producer of oil shale in Australia, the other interesting occurrences being those of Tasmania and Queensland. In Europe, the Esthonian shales are of both palæontological and technical importance; dry distillation of the material resulted in the production of 61 gallons of oil per ton, containing 20 per cent light fraction. The deposits of Yugo-Slavia (at Alexinatz) are valuable for their burning oil yielded on refining, while those of France, Spain, and Germany are sufficiently known to preclude further comment here. The resources of the United States are immense, some fascinating figures being given by Alderson in the work previously cited; the present author confines himself to mere statement of fact, though he omits reference to the difficulties met with in refining much of the shale hitherto tested. Finally, the discovery of shale deposits in Uruguay is important, and may lead to the opening up of a wide area in South America.

A map showing the oil shale-bearing districts referred to in the text is included, while a useful, though brief, bibliography is appended.

H. B. Milner.

The Nepheline Rocks of Sekukuniland. By S. J. Shand. Trans. Geol. Soc. S. Africa, vol. xxiv, 1921. pp. 111–49, with 3 plates and 6 text-figures.

THE nepheline-syenite body of Sekukuniland forms a plug or stock intruded into the red granite of the Bushveld laccolith, and has an outcrop of from six to nine square miles, occupying a

shallow depression surrounded by granite ridges. The junction between the syenite and granite can be fixed to within 100 yards or so except to the north, where it is covered by quartz-laterite, whose appearance is taken as approximating to the hidden junction. The intrusion is remarkable for the occurrence of a great limestone inclusion, the actual contact between the nepheline-syenite and the limestone being, unfortunately, hidden.

The rocks comprising the stock are all nepheline-syenites, ranging from extremely leucocratic to rather melanocratic, from almost saturated to highly undersaturated varieties. The amount of nepheline varies from being quite subordinate to being the principal light-coloured mineral, and the same applies to orthoclase and albite. The predominant dark mineral is a soda-bearing pyroxene, ranging from diopside to ægirine. Pale yellow sphene occurs, and apatite is abundant in some varieties. A titaniferous lime-iron garnet and primary calcite are also found. Cancrinite often replaces nepheline. Iron oxides and pyrites are extremely rare.

The author draws up a table showing the "subdivision of the syenoids", and takes three "ranges", the foyaite, ijolite, and canadite, characterized by the type of felspar (if any) with the nepheline. These "ranges" are further subdivided according to the percentage of dark minerals present.

A detailed petrographic description of the varieties of nepheline-syenite found in the area follows, special attention being paid to the contact facies of the foyaite.

The limestone xenolith occupies an area of at least ·57 square mile, and is a white crystalline marble, showing little sign of contact metamorphism, except recrystallization. In places, however, opal, crocidolite, and apatite, with some granular magnetite, are developed.

Speculation on the form and nature of the intrusion, and the source and mineralization of the limestone, and its bearing on Daly's hypothesis of the alkaline rocks, followed by a short description of the economic geology of the area, bring the paper to a conclusion.

R. S.

Elements of Engineering Geology. By Ries and Watson. Published by Chapman & Hall. Price 22*s*.

THIS is an excellent book, and one that should be included in the library of every engineer. Besides being a good general text-book on economic geology, the engineer's point of view prevails throughout.

The volume is a condensation of *Engineering Geology* by the same authors, parts having been re-written and amplified, and contains over 250 diagrams and illustrations; the greater part of these are from actual cases where the geological formations have been the outstanding considerations to the engineer.

Although the text deals largely with engineering problems encountered in the United States, they are identical with those to be met with in any part of the world.

Some interesting tables and other information for the drainage engineer are given in the chapter devoted to rivers, relating to the percentage of suspended matter carried by various rivers, which should impress the engineer and student with the desirability of investigating on similar lines the rivers in this country. The same chapter also deals with the ratio of run-off to rainfall, and here again the published information relating to streams in this country is comparatively scarce.

Excellent chapters are provided on underground water-supplies, road materials, and ore deposits.

At the end of each chapter is a comprehensive list of references consulted, the majority of which are the official bulletins of the United States Government, and to these the reader is recommended to refer; they are published free by the Government at Washington.

L. E. Wilson.

REPORTS AND PROCEEDINGS.

Mineralogical Society.

10th January.—Dr. A. Hutchinson, O.B.E., President, in the chair.

C. E. Tilley: Density, refractivity, and composition-relations of some natural glasses.

The glasses investigated fall into two groups, (*a*) tektite glasses, (*b*) volcanic glasses. The characteristics of the former confirm their divergence from volcanic glasses and support the theory of their meteoritic origin. The specific refractivity of five analysed glasses are compared with the values calculated from the specific refractivities of their component oxides and a notable correspondence is revealed. The influence of contained water on the specific refractivity is discussed and some figures are given bearing on the volume-change accompanying the passage from the vitreous to the crystalline state.

Dr. H. H. Thomas and E. G. Radley: On the so-called "Avanturine" from India, with an analysis of the contained mica.

The stone is a quartz-schist and owes its colour to plates of green fuchsite arranged parallel to the planes of foliation. The mica contains 1·77 per cent Cr_2O_3 and a little vanadium; its optical characters are described. The probable source of the stone is discussed and its deterioration by heat and other causes is explained.

A. Russell and A. Hutchinson: On laurionite and paralaurionite from Cornwall.

Laurionite associated with phosgenite and anglesite in a cavity in limonite is described in a specimen obtained from the collection of John Hawkins, of Trewithin, Cornwall. The locality is probably

Wheal Rose, Sithney. Paralaurionite occurs with phosgenite in a very similar specimen in the collection of the late H. J. Brooke, said to come from Wheal Confidence, Newquay.

A. Russell: On a discovery of pitchblende at Kingswood mine, Buckfastleigh, North Devon.

Pitchblende occurring in a north and south lode associated with chloanthite and native bismuth is described. The discovery shows promise of being of some economic importance.

W. A. Richardson: The distribution of oxides in Washington's collected analyses of igneous rocks.

Frequency curves are given for all the oxides and show considerable differences from those previously published. The silica curve is the most interesting and shows two maxima, one at 52 per cent and the other at 72 per cent SiO_2. The frequency curve for SiO_2 can be matched by a combination of two normal curves of error with origins on the 52 and 72 per cent lines.

W. A. Richardson: A simplification of the Rosiwal method of micro-analysis.

A method is described by which, using a drawing apparatus, the lengths of component minerals of a rock can be projected on to separate strips of paper and directly summed.

Dr. A. Schoep: On the absence of cobalt in cornetite from Katanga, Belgian Congo.

Microchemical tests made on carefully selected crystals from the original locality (Star of the Congo mine) prove that cobalt is present only in associated black spots of heterogenite. The mineral is thus a hydrated phosphate of copper, agreeing completely with that recently described from Northern Rhodesia.

Edinburgh Geological Society.

16th November, 1921.

1. "Note on the Dry Valley of Windy Gowl, Carlops." By the President, T. Cuthbert Day, F.C.S., F.R.S.E.

Mr. Day called the attention of students of Glacial Geology to this remarkably fine example of a glacial "Dry Valley", as one worthy of further study. He pointed out that Windy Gowl was probably a feature in the landscape before the time of the Ice Age, being partially carved out by the usual agents of erosion working along a narrow belt of land, where the underlying rocks have been shattered through faulting.

2. "The Glacial Strand-lines of Loch Tulla." By J. Mathieson, F.R.S.E., and E. B. Bailey, M.C., B.A., F.R.S.E.

High-level strand-lines occur above the head of Loch Tulla at altitudes of 1,041, 1,030, 1,020, and 816 feet above O.D. Of these levels the first and last have been determined by trigonometrical observation, the others by estimation.

During the whole period when the strand-lines were forming in succession, Loch Tulla was dammed by a glacier reaching down to Glen Orchy from the Auch Gleann behind Beinn Dorain. At an early stage Loch Tulla was also confined by a glacier blocking the alternative pass which leads by way of Loch Dochard into Glen Kinglass; and it was under those circumstances that its waters rose until they could escape northwards into the hollow of Loch Ba by cols which became available, one after another, at heights of 1,041, 1,030, and 1,020 feet respectively. Later, the pass to Glen Kinglass was barred and the waters of the Loch sank to 816 feet. Nowadays with Glen Orchy freed of ice, the surface level of Loch Tulla only reaches 542 feet.

3. "Note on the Occurrence of Norwegian Boulders near Ellon, Aberdeenshire." By Dr. Campbell and Dr. Gibb.

Dr. Campbell exhibited a boulder of typical Rhomb-Porphyry which he found *in situ* in a thin deposit of boulder-clay, three-eighths of a mile north-west of Arnage House, and four and a half miles north-north-west of Ellon. Dr. Gibb showed two specimens of typical Laurvikite—one collected by himself was found built in the walls of an old house 2 miles north of Ellon, the other was found many years ago in the Ellon district by the late Professor James Nicol. Two earlier records of the occurrence of boulders of Rhomb-Porphyry in Scotland may be recalled: (*a*) from a recent beach near Portsoy (Mr. H. H. Read, 1919); and (*b*) from a coarse boulder bed underlying the Lower Grey Boulder Clay at Bay of Nigg, Aberdeen (Dr. Bremner, 1920).

Evidence is not yet available to demonstrate whether or not the boulders in the Ellon district were transported directly by the Scandinavian Ice Sheet, but some significance perhaps may be attached to the fact that from the same district the late T. F. Jamieson described an "Indigo Boulder Clay" underlying the Lower Grey Boulder Clay.

21*st December*, 1921.

1. "The Source of the Purple Zircons in the Sedimentary Rocks of Scotland." By William Mackie, M.A., M.D., D.Ph.

In a former communication Dr. Mackie drew attention to the occurrence of purple Zircons in many of the sedimentary rocks of Scotland. These Zircons range in colour from faint purplish to a purple so intense as to render the crystal nearly opaque. As a rule they are distinctly rounded, varying from almost spherical through long regular ovoids to shorter, sometimes asymmetrical ovoids. The chief object of the present paper was to trace the source of these Zircons. Dr. Mackie has found that they are of frequent occurrence in the Moine Schists, in the Aberdeen Schists, in the Torridonian, and in all the younger sediments examined.

He states, as a broad generalization, that there has been a gradual decrease in the relative numbers of purple Zircons present in the sedimentary rocks of Scotland in the order of their age from earlier to later times. The purple Zircons rarely occur in Scottish granites, and, when they do occur, they are to be regarded as derived from the rocks through which the granite has been intruded. Dr. Mackie finds that in certain Archæan gneisses of the North of Scotland, the purple Zircons are unaccompanied by the normal Zircons of igneous rocks, and he has arrived at the conclusion that these Archæan gneisses are the original sources of all the purple Zircons found in later sediments. He described also similar Zircons from the "Banket" of South Africa, and from various Canadian rocks, and raises the question as to whether purple Zircons may not be characteristic of Archæan rocks in regions other than the North of Scotland.

2. "Note on the Exposure of St. Leonard's Crag, at No. 39 St. Leonard's Hill." By the President, Mr. T. Cuthbert Day, F.C.S., F.R.S.E.

There are several points of interest in connexion with this well-known but seldom visited exposure of the basaltic sill of St. Leonard's Crag. The chief among them is a peculiar line of fracture extending for some yards in a nearly east and west direction. Much material which would have furnished useful evidence has been quarried away. Mr. Day supposed the fracture to be contemporaneous with the intrusion, and that some of the sedimentary sandstones above the sill were drawn in, crushed, and mingled with fragments of some of the already partially consolidated basalt, the whole being subsequently bound together by a final phase of the intrusion, in which all the broken fragments were bound together by the injection of porphyritic basalt, largely in the form of a peculiar tachylyte.

During the discussion which followed, Mr. E. B. Bailey supplemented this explanation, and suggested as a cause of the fracture, that during the intrusion, there was an outburst of gas sufficiently strong to fracture the partially solidified sill, and to lift the presumably light cover, whereby a quantity of overlying loose desert sand fell into the fissure, filling many vacant spaces; a continuance of intrusion helped further to close the breccia as explained above, while subsequent infiltration of calcite completed the task. He also argued that the sill consists, broadly speaking, of a non-porphyritic portion earlier than the explosion, and a porphyritic portion subsequent to it; the non-porphyritic was cooled very markedly in the vicinity of the breccia by the time the porphyritic portion was injected.

3. Exhibits of (*a*) "Stones showing Sand-blasting and Insolation from the Culbin Sands." By Allan Grant Ogilvie, M.A., B.Sc. (*b*) "Garnetiferous Sand from above the Blackness (Limestone) Coal." By H. M. Cadell, B.Sc., F.R.S.E.

18th January, 1922.—Mr. T. Cuthbert Day, F.C.S., F.R.S.E., President, in the chair.

1. "A Basalt Laccolite at Bo'ness."
2. "The Edge of a Carboniferous Volcano."
3. Exhibit of Specimens showing Contact Alteration of Coal, etc.

By H. M. Cadell, B.Sc., F.R.S.E.

Mr. Cadell described a basalt laccolite in the Bo'ness Coalfield that had recently been proved in numerous borings to the Smithy Coal seam. Under a large part of the Bo'ness Coalfield there had long been known to exist a harmless bed of whinstone between the Main and the Smithy Seams, which differed from the inter-bedded basalt lavas of the district in being intrusive. At Bridgeness this rock, which was usually about 20 feet thick, suddenly changed its position and swelled into a lenticular mass that reached a thickness of 106 feet at one place, and formed a small laccolite such as had been found on a much larger scale in other countries. The effect of the intrusion was to destroy the coal within 10 feet of it, but the coal was not rendered anthracitic as it was converted into a hard carbonaceous mass full of calcite and chalybite veins of no economic value.

One interesting fact had been proved, viz. that the whinstone had been forced like a wedge between the strata without melting or absorbing any part of the surrounding rock. In one bore the whinstone had split the Smithy coal into two parts, and the upper half of the seam was separated from the lower part by a solid sheet of basalt 97 feet thick. A quarter of a mile away the unwelcome invader had shrunk to a sill only 4½ feet thick, and the coal was quite good only a few feet from it. The course of the sill was very erratic, and there were places where it did not occur at all, and much boring was required to ascertain exactly the amount of coal that was destroyed.

Specimens of the burnt coal and the basalt were exhibited.

Mr. Cadell next dealt with other volcanic phenomena of the Carboniferous Limestone period in West Lothian. The first eruptions at the close of the Oil Shale period were of ash, and later a great volcano situated to the west of Linlithgowshire poured out floods of lava which overwhelmed the forests and became inter-bedded among the coal-bearing strata as they were being deposited. Some deep bores had been made in search of coal to the west and south of Bo'ness, and, instead of finding useful minerals, had pierced nothing but lavas and ash beds more than 1,400 feet thick without getting through the volcanic pile. The Bo'ness Coalfield was on the edge of a large volcanic island that existed to the west, and on this great heap of lavas and ash beds the coal forests did not exist, or at least produce coal seams until the volcano became extinct after the Index Limestone was formed. A section was shown of the edge of this volcano as disclosed by bores and pits sunk through the volcanic rocks in that quarter.

Liverpool Geological Society.

13th December, 1921.—Professor P. G. H. Boswell, O.B.E., D.Sc., F.G.S., President, in the chair.

The following communications were read :—

1. "Note on the Natural Panning of Minerals in Littoral Deposits," by Nigel W. Kennedy.

The separation of the various mineral constituents of littoral sands by a purely natural aqueous agency has not hitherto been definitely recorded, and the author has therefore described his own observations during the past few months on the sands of the Mersey shore, where the process may be seen in operation.

Black sand, containing a great variety of rare heavy minerals, occurs in irregular patches of several square yards in area on the flat parts of the shore near the tidal limits, and also on the sides of ripple marks facing the sea. In the latter case the separation is held to be due to wave action alone, but in the former the sun's heat and prevalent strong sea breezes have also played a part, and the details of the process as observed were fully described. The results of observations on the mechanical separation of the constituents of dry sand on the slopes of dunes are also given.

2. "The Igneous Rocks of the Capel Curig District," by Howel Williams, B.A.

The district studied covers an area of some 10 to 12 square miles in the south-east corner of Snowdonia, with the village of Capel Curig as its centre. The dominant rocks are all igneous, either lavas, ashes, or dolerites, and the associated sediments are also largely the result of the breakdown of the volcanic rocks, so that the geology of the area is necessarily and primarily a study of vulcanicity. A general account of the vulcanicity of Snowdonia as a whole was first given, including a discussion of the related crustal movements, and a detailed description of the rock types in the localized area followed, together with a consideration of their position in the Ordovician series. The Capel Curig rhyolites according to the author's researches differ from those of the Snowdonian group proper in that they (1) are more porphyritic, (2) show banded and nodular structures, (3) are seldom associated with thick tuffs, (4) are garnetiferous and pyritiferous, (5) are freer from impurities (absorbed muds, etc.), (6) are generally less devitrified, (7) are richer in iron ores and viridite (also prochlorite and cordierite), while the Snowdon lavas (1) contain mispickel, (2) are usually highly mixed with tuffs, and (3) have not the thickness of the Capel Curig flows. Evidences of solfataric action are seen in the occurrence of garnets and in the associated tourmaline grits.

The tuffs can be classified as (1) purely vitric, (2) detrital vitric, (3) crystal and lithic, (4) agglomeratic tuff or breccia. The dolerites occur usually as sills and dykes, and with few exceptions are augite-dolerites of spilitic character. They include a peculiar differentiation-

product, a type of rock hitherto undescribed, and provisionally termed a biotite-porphyrite. The paper concluded with a discussion of the metamorphism induced by the dolerites, which has resulted in the production of spilosites and adinoles among the contact rocks.

10th January, 1922.—Professor P. G. H. Boswell, O.B.E., D.Sc., F.G.S., President, in the chair.

The following communications were read:—

(1) "On Peaty Bands in the Wallasey Sandhills." By W. G. Travis.

The principal band described is exposed on the seaward face of the dunes which fringe the Wallasey shore, and with the exception of one considerable gap where the dunes are broken down is visible for a distance of 1 mile 700 yards. The thickness on the whole is from 6 to 9 inches. A detailed study of the plant remains of the bands has been made, which has revealed an abundant moss flora, including nine species of *Hypnum*, several of which have never been found in a living state in the Wirral peninsula. From the evidence of these plant remains, and more especially the characteristic assemblage of mosses, in conjunction with the circumstances in which the remains are preserved, it is clear that these bands of peaty sand and silt are deposits which were accumulated in wet dune "slacks" such as occur in the flats or hollows among the sandhills on the Lancashire coast. They indicate the former existence of physical conditions in the Wirral dunes which do not now obtain. The correlation of the bands with similar superficial deposits recorded by previous observers was discussed.

(2) "Note on some fractured pebbles from Point Cranstal, I.O.M." By W. A. Whitehead, B.Sc.

A brief description was given of the glacial deposits in the neighbourhood of Point Cranstal, also known as Shellag Point, about 4 miles north of Ramsey town. The gravels and sands are often cemented into hardpan known locally as "scrablag", and the fractured and subsequently cemented pebbles occur in association with this. Several specimens were described, and their significance and mode of origin considered.

Yorkshire Geological Society.

17th November, 1921.

Mr. W. S. Bisat: Some Goniatite Zones in the Millstone Grit Series.

In the Millstone Grit Series of Yorkshire are a number of thin bands containing marine fossils, and layers of shale crammed with goniatites are frequently met with in these marine bands. The full succession has not been wholly worked out, but six zones are

recognized. The sequence of fossils consists of (in ascending order) *Glyphioceras Beyrichianum*, *Glyphioceras reticulatum* (type), *Glyphioceras reticulatum* (certain mutations, including *G. bilingue* (Salter)). Specimens of *Glyphioceras* approaching the characteristics of *Gastrioceras* in their mode of coiling and in ornament appear in abundance at horizons fairly well down in the *G. reticulatum* mutations beds; and near the summit of the Grit series they are very much in evidence. These specimens of early *Gastrioceras* differ considerably in their ornament from one another and form a complex group.

A study of the sutures of the above goniatites suggests that all the species belong to one group of closely allied forms. The *crenistria-sphæricum-striatum* group, which underlies the above zones and in Yorkshire characterizes the Upper Limestone Shales, is apparently (as was observed by Haug) a group distinct from the above. Very young sutures of *crenistria* closely resemble the adult sutures of the *reticulatum* group. A specimen of *sphæricum* has a spindle-shaped initial whorl. *G. Phillipsi* (F. & C.) appears to be a synonym of *G. striolatum* (Phill.).

CORRESPONDENCE.

PROFESSOR KENDALL ON ENGLISH ESKERS.

Sir,—Professor Kendall's article (Geol. Mag., March, pp. 98–103) is based on a series of misquotations and misrepresentations and complaints as to the omission of irrelevant evidence. His irresponsibility as a critic lessens my satisfaction at his agreement, in the two cases with which he deals, with the essential conclusions of my paper, viz. that the Lanshaw Delves is a moraine and not an esker, and that the group of drifts near York are not concentric kames connected by osar.

The Lanshaw Delves belong to a double series of glacial formations which Professor Kendall fails to distinguish. One is the Lanshaw Delves itself, a continuous bank of sandy loam and angular unglaciated blocks of Millstone Grit. The other is a series of denuded mounds of ordinary glacial drift which extend for three or four miles eastward of the Lanshaw Delves and contain an abundance of Carboniferous Limestone. Professor Kendall misapplies the latter part of a paragraph from the Geological Survey Memoir on the Yorkshire Coalfield to the Lanshaw Delves. If he had included the first three lines of that paragraph it would have been clear that the part he quotes refers not to the Lanshaw Delves, but to some drift mounds miles eastward from it. The quotation is from the end of a section headed "High-level Eskers". Its first paragraph describes the Lanshaw Delves (p. 779), and the gravel mounds near Hawksworth. The second paragraph (p. 780) refers to the length and slope of the drift ridges. The third paragraph begins: "Besides the above there are several isolated mounds and banks

of this same gravel at Swartha Wood, Stocks Gate, and Askwith; at this last place, which is on the opposite side of the Wharfe, the gravel is only 425 feet above the sea. These mounds have been dug over," etc. The "these mounds", old lime-kilns and burnt stones, of the quotation by Professor Kendall are those at Swartha Wood, Stocks Gate, and at Askwith, which is four miles north-east of Lanshaw Delves.

The interest of the Lanshaw Delves in connexion with the esker question is that it was claimed as a high level esker; if so it is exceptional, and its explanation appeared difficult. I attached importance to this identification as it had been accepted by A. H. Green, whose work on eskers elsewhere gave weight to his opinion. Professor Kendall says that when I mentioned Green I meant Russell. That is not so. I referred to Green as the preface to the Memoir on the Yorkshire Coalfield states that he edited the whole of it, and internal evidence (e.g. the modification of the views expressed by Russell in 1873) suggests that Green wrote these paragraphs in the Memoir. Russell in 1873 said that the ridges including the Lanshaw Delves seem "to be undoubted eskers"; the text of the Memoir reduces this statement to "esker-like". According to the Preface to the Geological Survey Memoir, 92 S.E., 1879, the field-work for the Survey on the area including Lanshaw was done, not by Russell, but by Fox-Strangways! My impression from Russell's statements was that he had probably never seen the Lanshaw Delves. I did not quote the literature before 1878, as Green doubtless considered it all when preparing the paragraphs in the Yorkshire Coalfield Memoir.

The interpretation of the Lanshaw Delves as a moraine instead of an esker had three preliminary difficulties. First, the angular, unglaciated nature of the grit boulders. Second, the great difference in form of this bank from the neighbouring drift formations. It is so conspicuous that it is marked on half-inch-to-the-mile topographic maps, and is so regular that it has been often claimed as an artificial prehistoric earthwork. The name "Delves" appeared to support that view; accordingly before my visit I looked up the word in Wright's English Dialect Dictionary, where, among other meanings, is its use in West Yorkshire for to "split or rive the flag-rock". In that sense it seemed possible that the name had been suggested by the condition of many flagstone boulders in the Delves. The term is also used, as quoted by the *New English Dictionary*, for a sudden dip or slope of a hill, or for the descent of a path. Etymology, therefore, gave no definite help. I saw evidence of digging in the Delves, but nothing to decide whether it was to obtain limestone boulders from underlying boulder clay or was connected with the possible use of the bank as a prehistoric earthwork. Third, the absence or rarity of Carboniferous Limestone was a further difference from the adjacent glacial drifts. I did not say or conclude, as Professor Kendall seems to have inferred, that there was no Carboniferous Limestone in the Delves, for—as quoted in my paper—the Survey Memoir states

that the banks south of Ilkley sometimes rest on boulder clay; if that be the case with the Delves it would be strange if some Carboniferous Limestone material had not been included in that bank. In a much shorter examination of the mounds further east I saw plenty.

These objections to the morainic origin do not apply to the explanation of the Lanshaw Delves, which seems to me probable. The bank strikingly reminded me of some Scottish corrie moraines. In suggesting this explanation I did not deny either the former or contemporary existence of ice to the north of it, by which the drift mounds may have been formed as the lateral moraine of a Wharfedale glacier. On that question I have expressed no opinion. Whatever the origin of the mounds I regard the Lanshaw Delves as a later and more local formation.

I am obliged to Professor Kendall for calling my attention to the account of the Lanshaw Delves in the valuable paper by Jowett and Maufe; he remarks that my omission to quote it is unaccountable. I may therefore explain that in looking up the literature I trusted till the year 1914 to Shepherd's valuable bibliography; not finding any reference in its index to Lanshaw Delves, I examined the papers dealing with Ilkley and the valley of the Wharfe; but as Messrs. Jowett and Maufe's paper was entitled "The Glaciation of the Bradford and Keighley District", I did not expect to find any account of the Delves in it. I am glad to find that according to Messrs. Jowett and Maufe the top of the moor near the Lanshaw Delves was never covered by ice, and that they had already identified the Lanshaw Delves as a moraine.

The one formation in England for which there was high authority for identification as a "high level esker" (Moel-y-Crio, which is in North Wales, is so fragmentary that the case for it was less definite) is shown by Professor Kendall's article to be now unanimously accepted as a moraine, and the problem of the English eskers is thereby much simplified.

In regard to the drifts on the Aire Valley I agree with Professor Kendall that my paper gives no full account of them. It merely records facts which led me to agree with the Geological Survey Memoirs that these "gravel mounds" (e.g. Geol. Surv. Mem., 92, S.E., p. 12) were deposited in water.

In the case of the York and Escrick drifts it is unnecessary to follow Professor Kendall's summary of the history of the morainic theory. He misquotes me as describing "the two ridges as consisting of sand and gravel". I made no such statement. The remark which Professor Kendall has misquoted is that "Two curved bands of glacial sands and gravels occur . . ."; they occur upon the ridges which, as is clearly shown in the Geological Survey maps, consist mainly of boulder clay. Boulder clay does not form kames and osar; the possibility of those formations occurring near York is restricted to the bands of sand and gravel.